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Technical Report

SALVAGE WORK PROJECTS—SEALAB III

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SALVAGE WORK PROJECTS—SEALAB III

Technical Report R-684

56-007

by

John J. Bayles

ABSTRACT

The Navy is authorized by public statute to provide salvage facilities to assist both public and private vessels. In keeping with this responsibility, the Supervisor of Salvage, U.S. Navy, is prosecuting a vigorous program to incorporate the latest techniques and equipments into the Navy's salvage forces.

The SEALAB III program, under the direction of the Ocean Engineering Branch, Deep Submergence Systems Project Office, was initiated to advance the state-of-the-art of man's capability to live and work in the deep ocean environment. It was the goal of the Salvage Projects for SEALAB III to demonstrate and field test some of the more important new salvage devices and techniques.

This report discusses the aquanaut familiarization and training phases associated with the Salvage Projects planned for Team Two—SEALAB III, and the modifications to both equipments and procedures as suggested by the divers. Preliminary results are included with recommendations regarding future plans.

Human factors studies were conducted in conjunction with the training phases in preparation for SEALAB III. Goals included assessment of divers performance, the development of improved underwater work procedures, and improvement of underwater equipment design through development of design criteria.

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INTRODUCTION

For centuries, new and improved methods of applying positive buoyancy to submerged objects have been of prime interest to men engaged in work beneath the sea. Collapsible buoyancy devices (bridge pontoons) were introduced in the sixth century B.C. by Cyrus the Great. Although not recorded, early sailors probably employed hauling lines tended from surface craft. This implies consideration and development of materials, equipments, and techniques.

Additionally, over the intervening years, divers and sailors have had a continuing requirement for improved tools, both hand-operated and powered. In comparatively recent times, compressed air tools have served well in relatively shallow water. Unfortunately, however, salvage and other underseas work requirements are not limited to shallow depths and the requirement for other more applicable power sources arises. In the past decade, the depth to which man has been able to extend his capability to do useful underwater work has been dramatically increased.

Congress has authorized the Navy to provide salvage facilities for both public and private vessels. In keeping with this responsibility, the Supervisor of Salvage, USN, is prosecuting a vigorous program to incorporate the latest techniques and equipments into the salvage forces. This effort includes the development of new equipment and methods where required and the improvement of some of the older proven systems. Several of the newly developed devices resulting from this program have been demonstrated and field tested during training exercises conducted with the Mark I-Deep Dive System of the Supervisor of Salvage.

Human factors studies (see Appendixes A, B, and C) were conducted in conjunction with the training and had been planned for SEALAB III. Goals included assessment of diver performance with relation to increasing depth, development of improved underwater work procedures, and improvement of underwater equipment design criteria.

The overall objective of the Salvage Lift Systems Tests portion of this effort is to demonstrate the feasibility of conducting long term salvage operations with mixed gas saturated divers and to determine the capability of these divers to accomplish strenuous salvage work during prolonged dives. Lift systems play a highly important role in marine salvage. They are a common requirement in many operations. The specific objectives of the lift system tasks are to demonstrate diver procedures and to conduct both shallow and deep water field evaluations of the following lift systems:

1. Hunley-Wischhoefer remote recovery salvage attachment system

2. An 8.4-ton lift capability collapsible salvage pontoon

3. A 2-ton lift capability collapsible self-inflatable pontoon employing a self-contained hydrazine gas generator

4. A small, rigid, variable buoyancy self-inflatable device with a self-contained hydrazine gas generator for lifts of up to 200 pounds

5. Various combinations of the above systems and combinations incorporating a 25-ton lift capability padeye attached by explosively driven studs

In addition to determining the capability of divers to accomplish strenuous salvage work during prolonged dives, the specific objective of the second or Underwater Tools Tasks portion of the effort was to demonstrate procedures and to conduct both shallow and deep water field evaluations of the following tools:

1. Electric underwater power tool

2. Air driven saw

3. Explosively actuated cable cutter

4. Explosively actuated stud driver

5. Common hand tools

A further purpose of the tests was to compare baseline data—criteria established by Team Two aquanauts in shallow-water tests— with the performance of the same diver team under saturated conditions and in the hostile environment of deeper continental shelf depths at sea.

One of the more perplexing problems confronting divers at work in the ocean depths is the nature of the sea floor itself. More often than not, the bottom and the object of the work are covered by a fine sediment easily disturbed and sent into suspension by diver movement. The suspended sediment obscures diver vision to varying degrees. Various methods have been proposed to alleviate this problem. One such proposal has been the subject of a development program; the procedure is being tested and demonstrated in shallow-water exercises and will be applied at the deeper depth. The principle of the procedure is to utilize a dissolved plastic with a specific gravity greater than that of seawater. The material is spread upon the bottom in a thin sheet where the water soluble solvent is leached out, leaving a tough film covering the sediments.

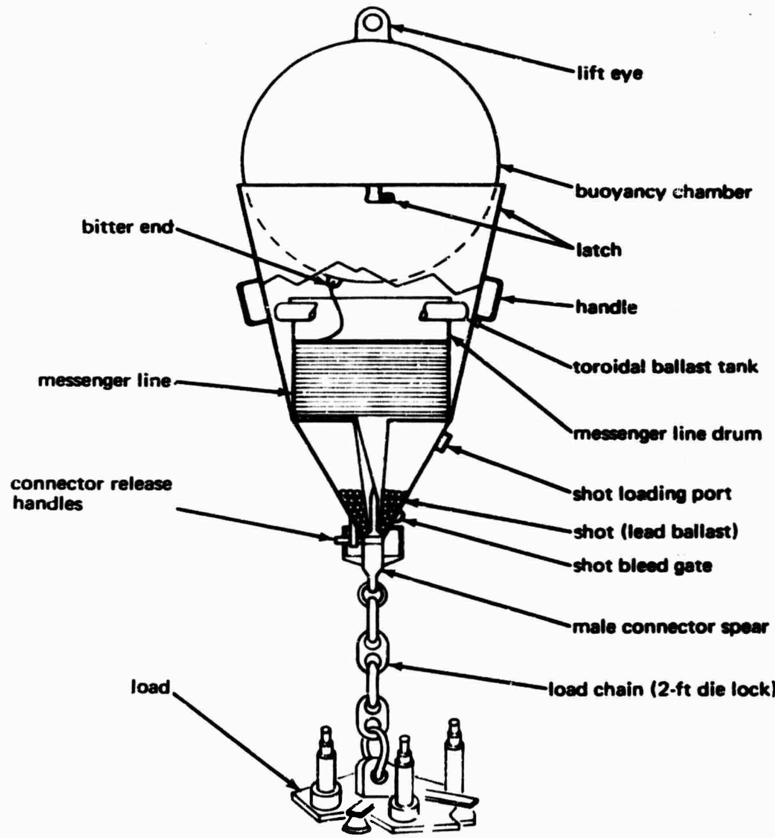
Safe lighting methods are being investigated. Several factors contribute to a requirement for artificial lighting of a work site. Nocturnal darkness, work inside or beneath objects, excess suspended particulate matter which obscures natural daylight, and normal increasing darkness with increasing depth are elements contributing to the need. Electrical lighting sources are recognized, but are not without their obstacles. They may require umbilicals, or cumbersome packaging if detached. If detached, their power-weight-size ratios must be considered. Chemical light sources have been developed and are a subject of the testing program.

DESCRIPTION OF TEST SYSTEMS

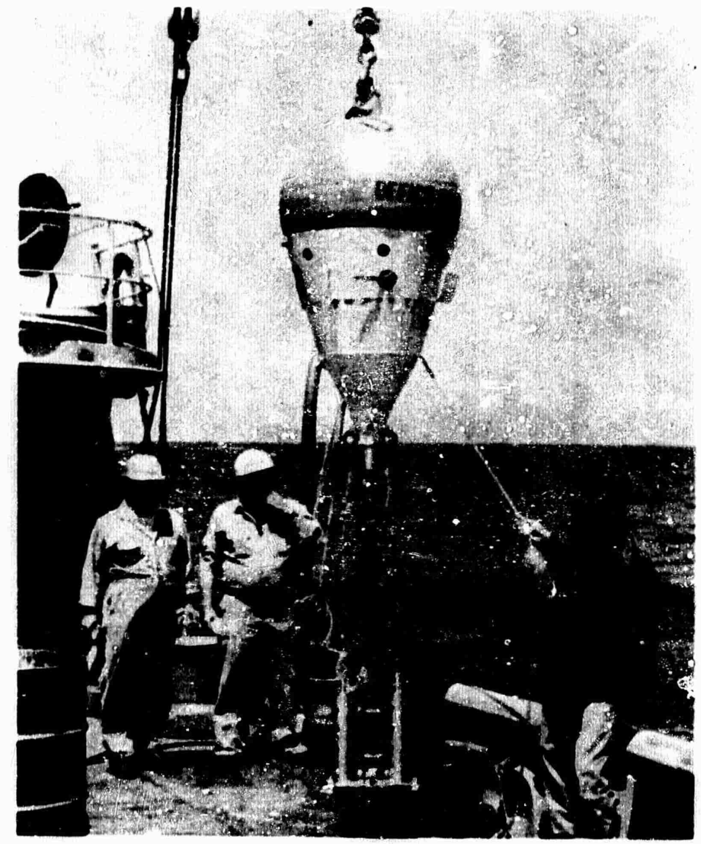
Hunley-Wischhoefer Remote Recovery System

The remote recovery system consists of a 30-inch-ID, 1/4-inch-thick mild steel, spherical buoy weighing 200 pounds, which rests in the large end of a conical steel fairing and is securely latched to it. The fairing contains a compartment for lead-shot ballast, a cylindrical drum containing 750 feet of 1/2-inch-diameter, polypropylene messenger line, and a toroidal ballast tank (Figures 1 and 2).

Fitting snugly into the bottom opening of the conical fairing and projecting upward into the shot ballast compartment is a notched male overshot-connector spear or prod, about 16 inches long and 2 inches in diameter, with a heavy base which has an eye for attaching a shackle to the load chain (Figure 3). The spear is locked in place in the fairing with two release handles which are held in place with safety pins.



(a) Sectional view.



(b) Assembled view.

Figure 1. Hunley-Wischhoefer assembly with 25-ton padeye.

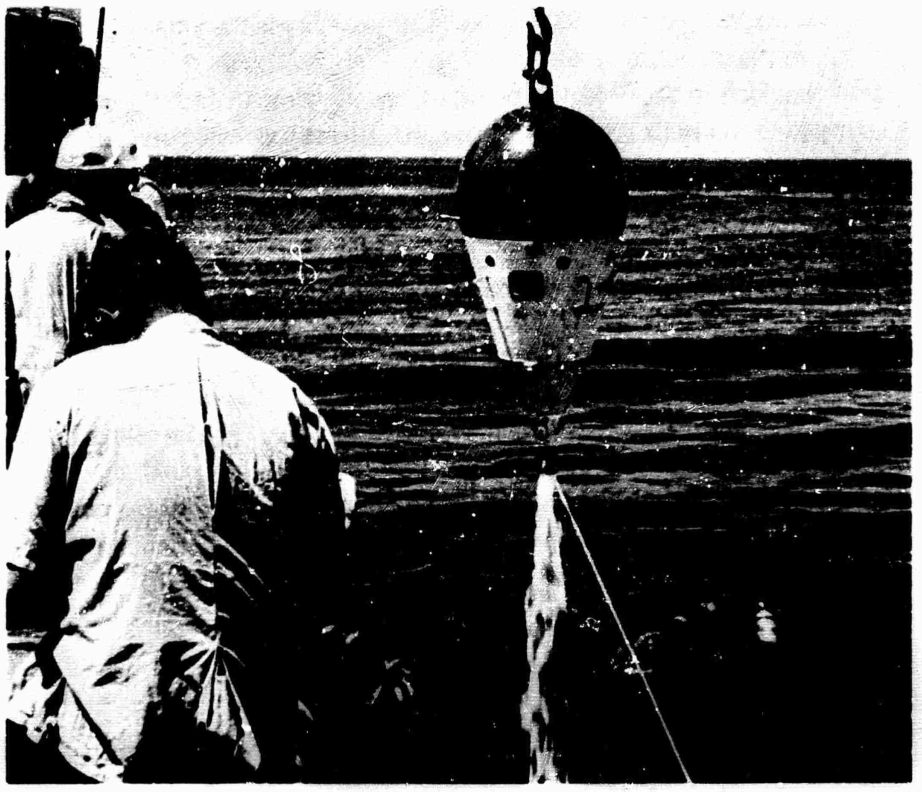
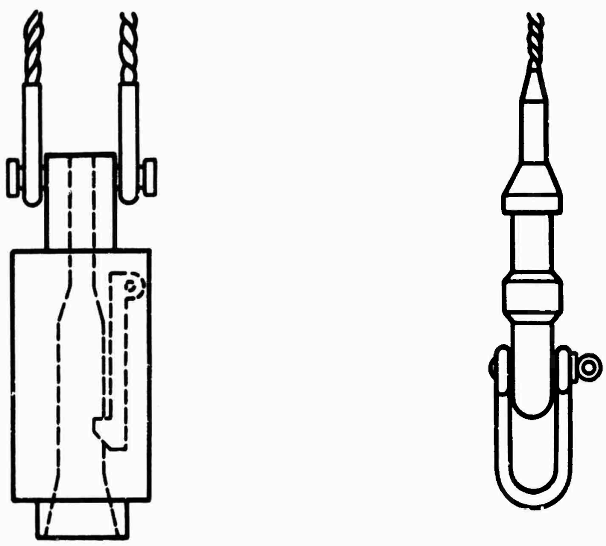


Figure 2. Retrieving the Hunley-Wischhoefer assembly.

A separate part of the Hunley-Wischhoefer system is a female overshot device about 12 inches in diameter and 24 inches long with a 2-1/2-inch-diameter, longitudinal, cylindrical center opening. Three spring-loaded locking lugs extend into the opening (Figure 3). A heavy wire rope handling bridle is attached to the top of the female overshot device.

In operation, the running end of the polypropylene messenger line, from the drum installed inside the fairing, is fastened into the nosepiece of the locked-in-place male connector spear and the shot ballast compartment is filled with lead shot (the amount required to overcome inherent positive buoyancy of the system). The buoy-fairing assembly is lowered by a ship's line to the sea bottom where divers disconnect the ship's lowering line. The assembly is then adjusted to neutral buoyancy by slowly bleeding ballast shot from a shot bleed hole. If too much shot is released, positive buoyancy can be reduced by allowing water to bleed into the toroidal ballast tank. Valving is provided for this purpose. The assembly is then maneuvered by divers to the object to be lifted. When the free end of the load chain has been shackled to the object to be lifted, the diver removes the release handle safety pins and pulls the handles clear. This frees the male connector spear from the buoy-fairing assembly. As the buoy-fairing assembly moves upward, the remaining shot in the ballast compartment spills out through the bottom opening left by the removal of the male spear. The assembly accelerates upward, paying out the polypropylene messenger line between the male connector spear and the surface.

On the surface, the ship's crew retrieves the assembly, Figure 2, cuts the messenger line, threads it through the female overshot device, and secures the free end of the messenger line to the ship. The female overshot device is then lowered by heavy wire rope lifting line (Figure 4), down the messenger line until it slips over the male connector spear and the overshot locking lugs engage the male spear notch, fastening the two units together. The object to be lifted can then be raised with the wire rope lifting line.



(a) Female overshot device.

(b) Male connector spear (prod).

Figure 3. Hunley-Wisc!.hoefer female overshot and spear.

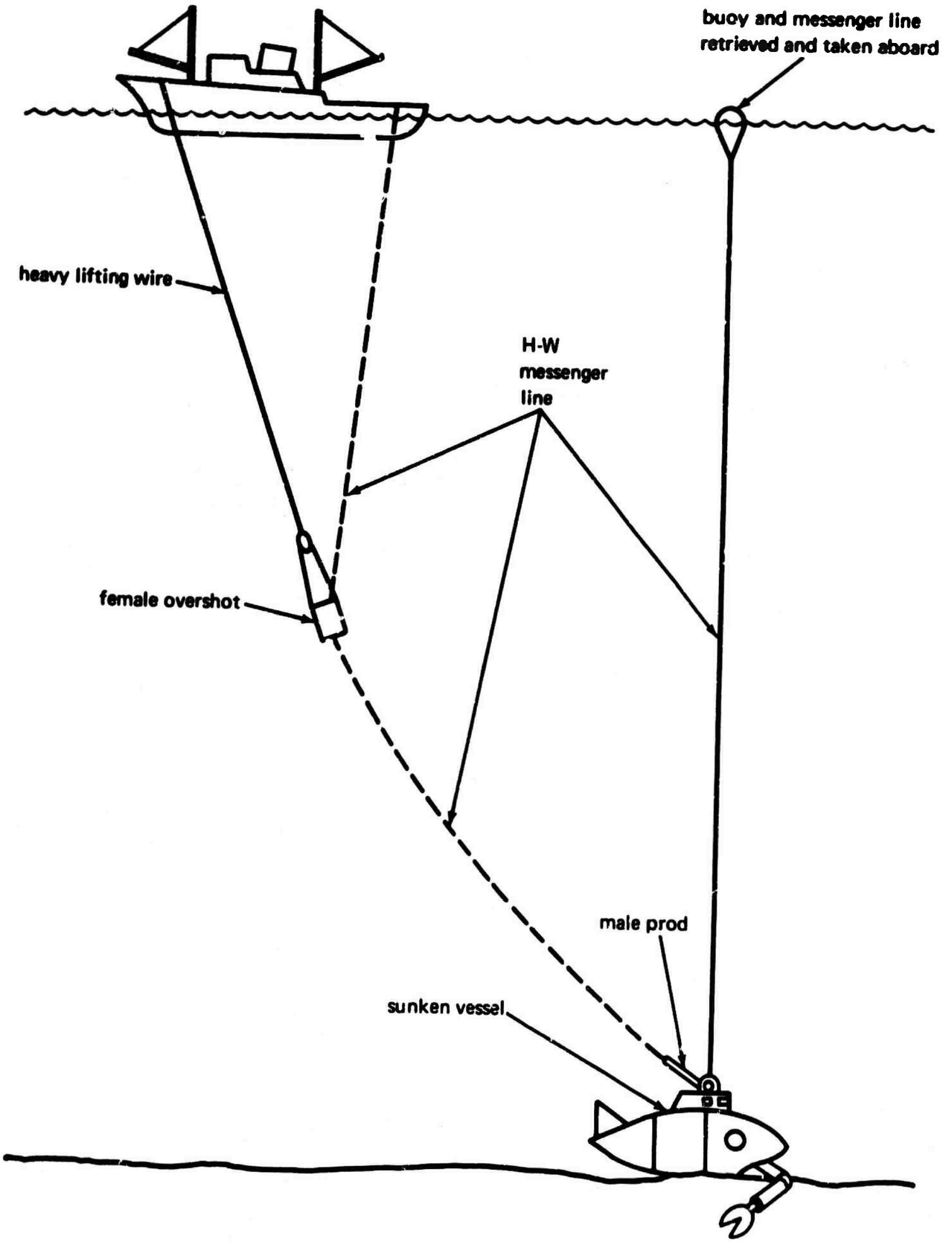


Figure 4. Hunley-Wischhoefer rigging schematic.

For SEALAB III exercises only, a dragskirt and lead weights were provided to decrease the terminal velocity by reducing the positive buoyancy of the ascending buoy-fairing assembly, as a safety precaution relative to the surface vessels.

Collapsible Salvage Pontoon With 8.4-Ton Lift Capability

The test pontoon was fabricated by the B. F. Goodrich Company under NAVSHIPS Contract NOBS-94517 in accordance with Specification Ships-P-5136. The pontoon has a buoyant lifting capability of approximately 8.4 long tons in seawater when fully inflated with a gas. It is fabricated to the configuration shown on the B. F. Goodrich Company Drawing No. 5FC1021, and has the following characteristics.

When inflated in air, the pontoon carcass is cylindrical in shape, 86 inches in diameter, and 87 inches long (Figures 5, 6, and 7). The dry weight of the pontoon is approximately 750 pounds and, when bundled for stowage, the pontoon can and should be stowed in a 45-cubic foot container (70 by 54 by 20 inches) for protection.

The pontoon is similar to an off-the-shelf, bin-type, bulk shipping container. It has a 19-inch-diameter end plate at the top and a 13-inch-diameter end plate at the bottom. Each plate has two integral padeyes. The padeyes within the pontoon, one on each end plate, are rigged to a central load-bearing stud-link chain. The external padeyes are used for handling and/or rigging to a load. The padeyes and chain have been tested in tension to 116,000 pounds.

The inflation assembly for attachment of the compressed air line is installed at the top; alternately it may be installed at the bottom. The bottom port is normally plugged. The inflation assembly consists of a 1-1/4-inch galvanized steel elbow, a short length of 1-1/4-inch pneumatic hose, a 1-1/4-inch bronze ball valve, and a 1-1/4-inch Roylyn No. 1022-20 bronze quick-disconnect nipple. Two relief valves are provided; one at the top is set to open at 5 to 6 psig and the other, at the bottom, is set to open at 2 to 3 psig. When properly set, the bottom valve should be first to relieve.

Two-Ton Lift Capability Collapsible Salvage Pontoon With Gas Generator

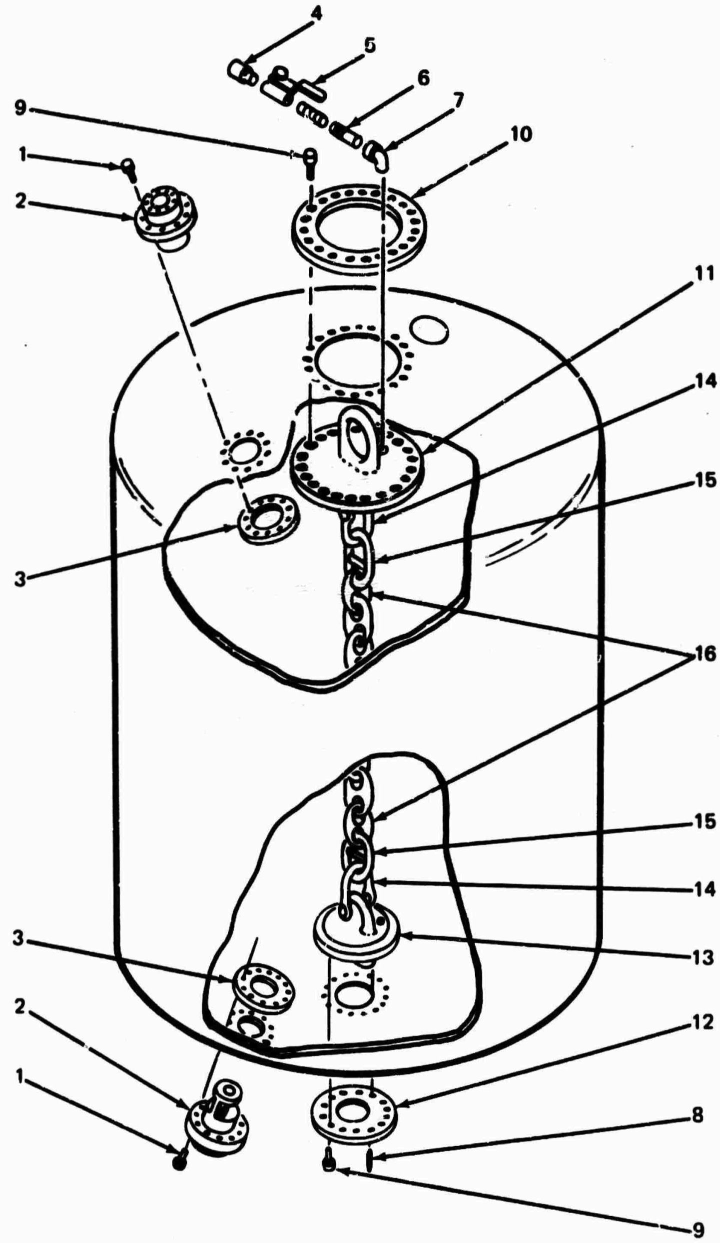
This salvage pontoon is a rubber-coated nylon bag 64 inches in diameter and 64 inches high, displacing 70 cubic feet and providing approximately 4,000 pounds of lift (Figure 8). It is balloon shaped with a slightly conical bottom half. Straps of nylon webbing form a loop at the top, run vertically down the sides, and form a second loop at the bottom for attaching a shackle. The bottom is closed by two steel discs bolted together. Several holes are provided in the rubber fabric just above the discs to permit water to pass freely in and out of the pontoon and to relieve over-expansion of inflation gases. Inside the conical bottom section and fastened to the bottom plate is a hydrazine-fueled gas generating unit with an expandable rubber fuel bag (fuel-fill pressured) and a hand-operated fuel control valve. A vertical zippered opening in the lower sidewall of the pontoon permits access to the gas generating unit. A vent valve provided in the top of the pontoon, to be operated by a lanyard, may be used to regulate lift forces and to deflate the device.

In operation, the unit is lowered to the work site by a ship's line and shackled to the load. The fuel valve for activating the gas generator is operated by a diver. The generated gas rises to the top of the bag while displaced water passes out through the drain holes at the bottom.

Variable Buoyancy System With 200-Pound Lift Capability

The variable buoyancy system consists of a two-section, rigid, cylindrical fiber glass capsule with hemispherical ends, approximately 4 feet long and 16 inches in diameter with a dry weight of 60 pounds (Figures 9, 10, and 11). In use in the water, it is oriented with the long axis vertical. The lower hemispherical end contains a spring-loaded, hydrazine-fueled gas generator with a handhole for access to the hydrazine fuel control valve. The upper hemispherical end and the cylindrical sidewall are a single piece with a vertical slot approximately the full length of the sidewall. The slot is closed by a strip of rubber-coated fabric with a full-length self-sealing zipper. A double-acting zipper slide opens the zipper in the direction of movement and closes it behind as it is moved up or down. A gas-bleed orifice is in the center of the slide. This provides a means for regulating the gas bubble volume within the shell. A scale painted at the side of the slot indicates the required position of the bleed hole for a lifting force of a given amount—up to 200 pounds. There are ring bolts at the top and bottom of the capsule shell for attaching lift lines and loads.

This system provides for a fixed lift force regardless of depth. As the system rises under diver control to a lower ambient pressure area, the expanding gas bubbles out the bleed hole maintaining constant trapped gas volume. If the system is carried downward to a higher pressure area, the gas generator can be turned on to provide an additional gas flow to compensate for compression of the gas in the buoyancy chamber.



1. Cap screw
2. Relief valve
3. Clamping ring
4. Quick-disconnect nipple
5. Ball valve
6. Hose assembly
7. Street elbow
8. Pipe plug
9 Cap screw
10. Closure ring
11. End plate
12. Closure ring
13. End plate
14. Bending shackle
15. End ink
16. Die lock link

Figure 5. Schematic of 8.4-ton pontoon assembly.

Figure 6. Three 8.4-ton pontoons rigged in tandem.

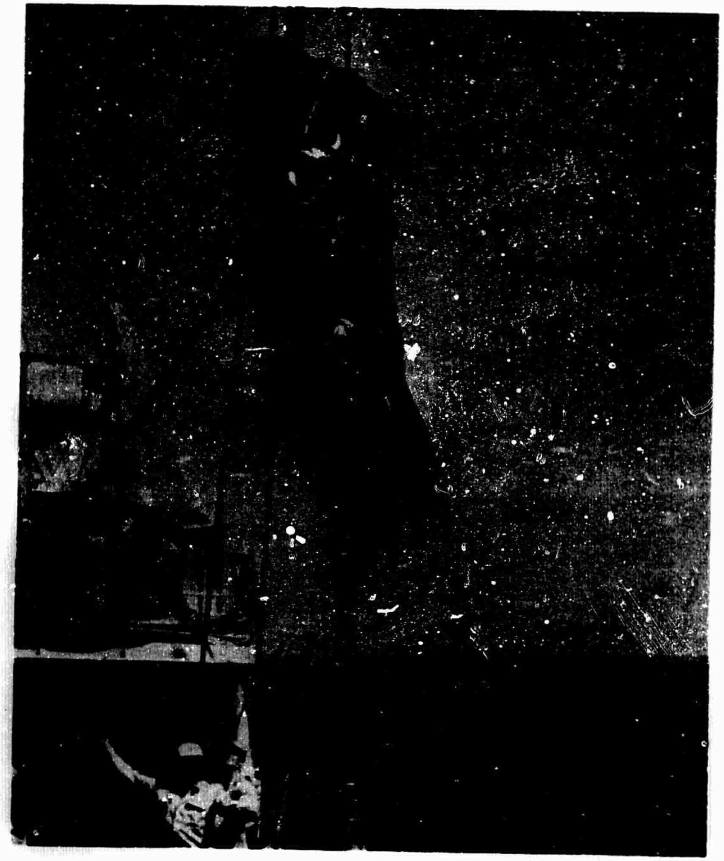
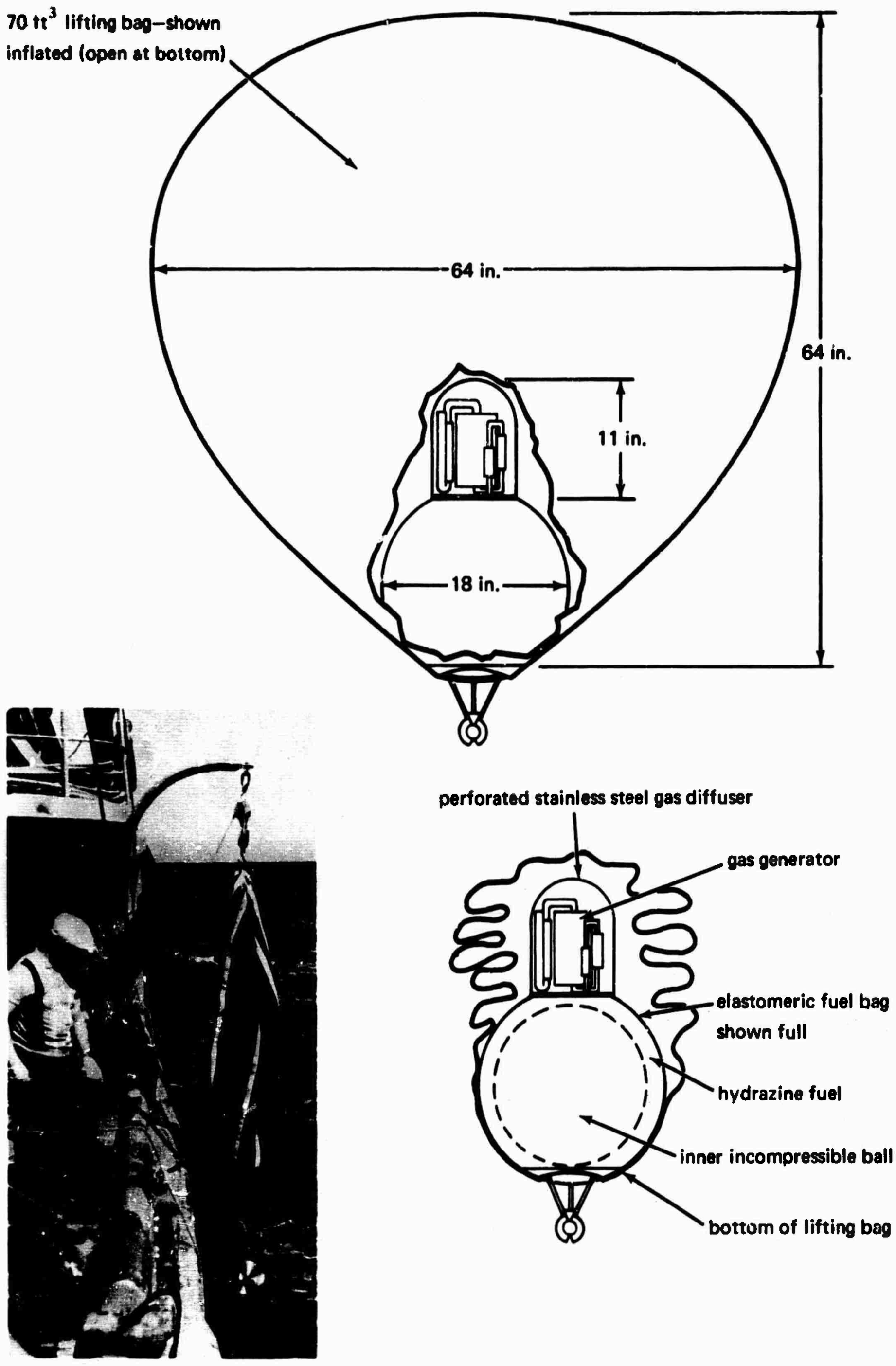


Figure 7. Retrieving the 8.4-ton pontoon with Hunley-Wischhoefer female overshot.



(a) Lowering pontoon.

(b) Sectional views.

Figure 3. Hydrazine-fueled 2-ton lift pontoon.

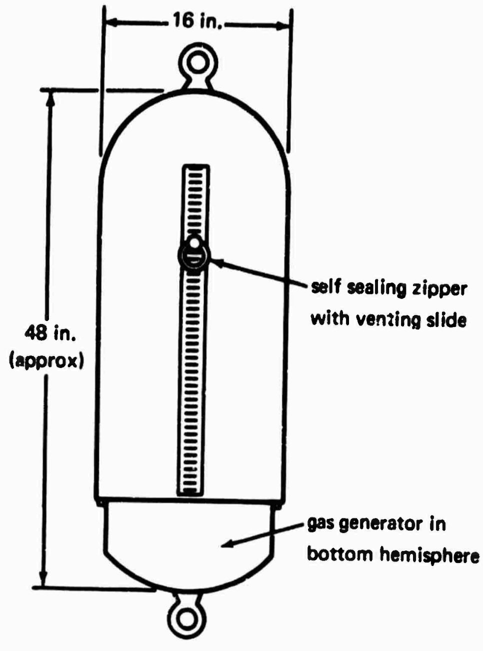


Figure 9. Hydrazine-fueled lift device with 200-pound capability.

Figure 10. Hydrazine-fueled gas generator for 200-pound capacity lift device.

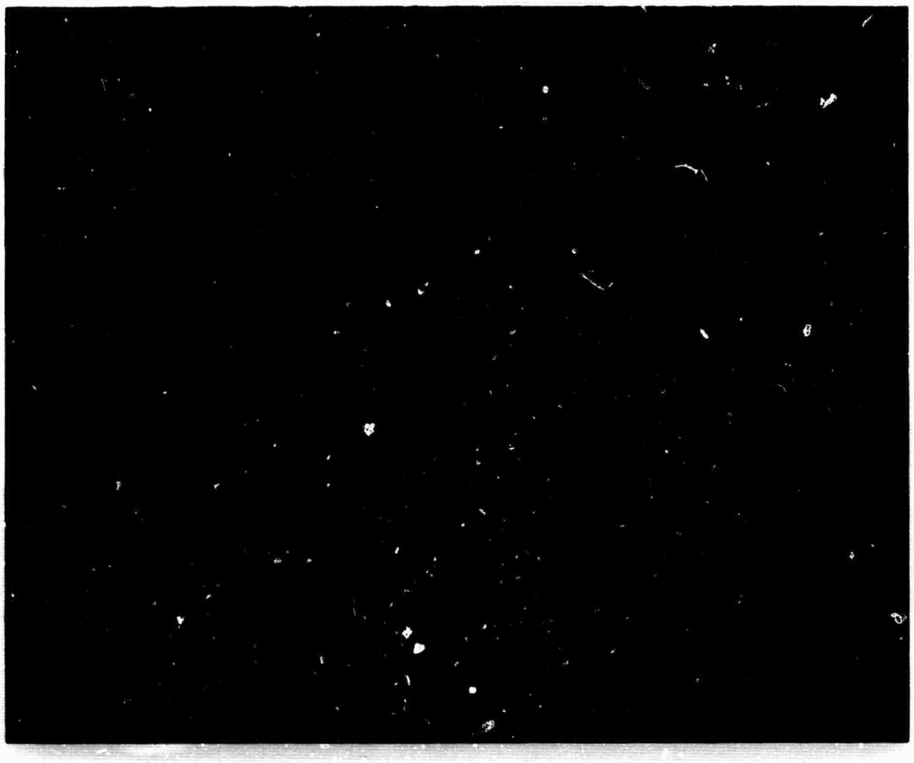


Figure 11. Hydrazine-fueled 200-pound capacity lift device in use.

Padeye With 25-Ton Lift Capability

The 25-ton lift capability padeye (Figures 12, 13, and 14) is an assembly which consists of a four-armed baseplate with a centrally located swiveling eye. A removable link is attached to the eye. A counterbored hole near the end of each arm provides a seat for a stud-cartridge-loaded barrel assembly. Magnets are attached to gimbals mounted between the four arms. The four magnets hold the padeye assembly in position on either a flat or gently curved ferrous surface of a salvable object while the stud-cartridge barrels are installed and fired to fasten the padeye in place. Cylindrical restraining cages with separate inner coils of aluminum tubing, which act as a shock absorber, contain the reaction of the barrel as a round is fired.

Each barrel assembly is screwed onto an adapter fitted into the padeye baseplate. These adapters guide the stud projectiles into place. Each barrel is designed to receive a firing mechanism capable of being fired remotely by lanyard.

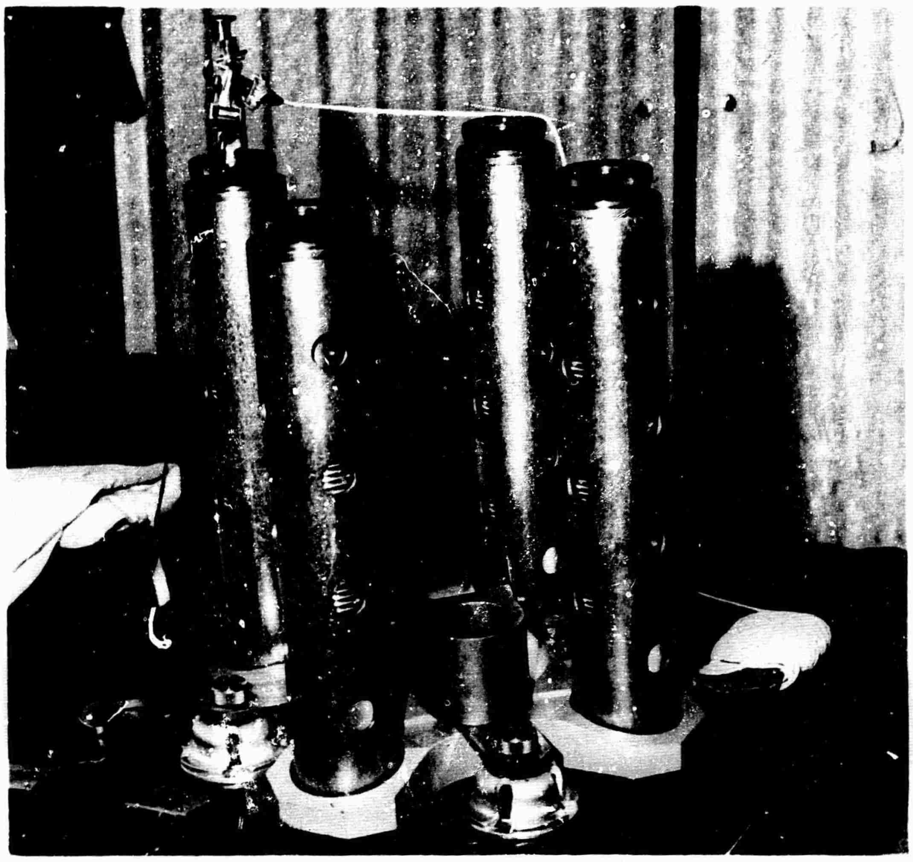


Figure 12. Twenty-five-ton padeye with firing mechanism installed.

The padeye is designed to be attached to 3/8 to 1-inch-thick HTS plate and to 1 to 2-7/16-inch-thick HY-80 steel. The design calls for the padeye to sustain a steadily applied load of 50 long tons for 8 hours at depths to 1,000 feet, in seawater temperatures from 28° F to 90° F.

Chemical Overlay System

The bottom stabilization system (Figure 15) is an assembly that consists of a chemical holding tank and a high-pressure air tank manifolded and valved such that the diver may select to discharge either air or air-pressurized chemical through an umbilical terminating at an applicator (spreader).

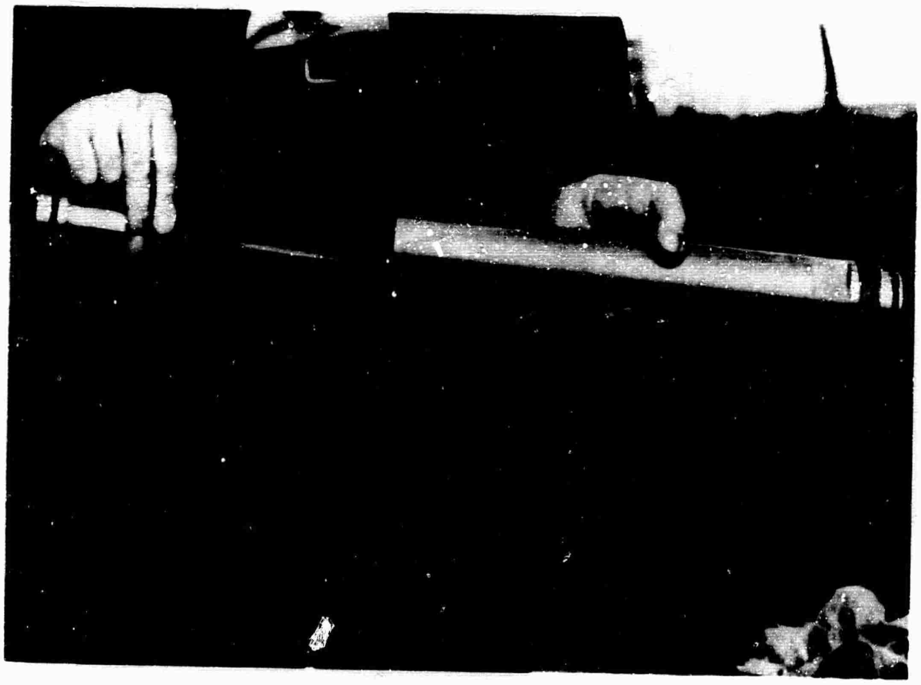


Figure 13. Twenty-five-ton padeye projectile and barrel.

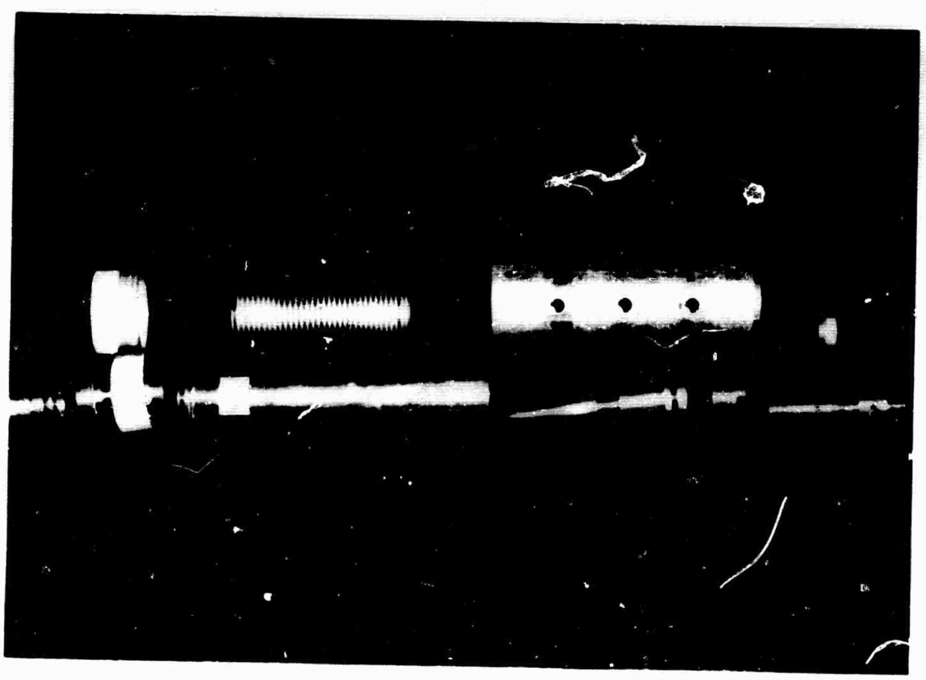
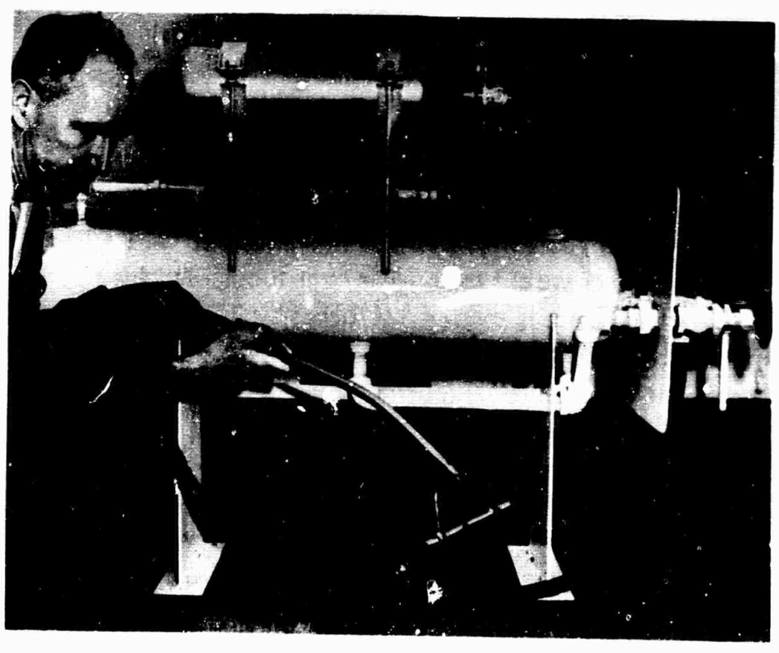


Figure 14. Exploded view of 25-ton padeye and stud firing assembly.

(a) Front view.



(b) Side view.

Figure 15. Chemical overlay system.

The diver first opens the air tank valve. An air pressure regulator at the tank reduces the pressure in the line to 100 psi above ambient. Intermediate valves are then opened to charge the manifolding lines with air and overlay chemical. These lines terminate at a three-way valve. This three-way valve is then opened to AIR to purge seawater from the umbilical hose and applicator. When the hose is cleared, the three-way valve is switched to OVERLAY. As the chemical emerges, it is spread upon the surface to be covered. Each successive pass should overlap the previous pass by 3 to 6 inches. The chemical will bond together, forming a continuous sheet.

The chemical used in the system is polyvinyl butyral mixed with a water soluble solvent. The migration of the solvent from the solution leaves a resin film that increases in toughness with time. Added plasticizers in the solution, with adequate specific gravity, aid in holding the film in place.

For use in the SEALAB III exercise, the system was to be mounted on the tool test stand and the chemical discharged into a tray of sand also on the stand (Figure 16). This would accomplish two purposes: permit examination of the material when returned to the surface and prevent divers disturbing the material as it sets up, during the exercise of their other duties.

Chemical Lights

The chemical lights consist of two fluids, organic in nature, packaged in two-part transparent containers. To initiate chemical reaction resulting in release of radiant energy, a separating barrier is broken and the fluids are mixed together. Light energy is released instantly. Three typical examples of the lights are illustrated in Figure 17.

The lights are positively buoyant in seawater so care must be exercised to secure or weight them. The large tubular light is 12 inches by 1 inch. The small device is about 4 1/4 inches by 3/8 inch. The pouch measures about 4 by 7 inches. The devices may be used alone to provide light in all directions or a supplemental reflector may be used to direct the light.

Electric Underwater Power Tool

The underwater tool (preprototype model shown in Figure 18) is electrically powered with a 5/8-hp, open, water-cooled and water lubricated AC motor (60 Hertz, 110-120 volts). It weighs 20 pounds in air and 15 pounds in water. The tool has accessories (Figure 19) that permit drilling, tapping, impacting, reaming, grinding, and hole sawing. An electrical safety circuit is incorporated in the system design to interrupt power to the tool and connecting lines in the event of insulation failure.

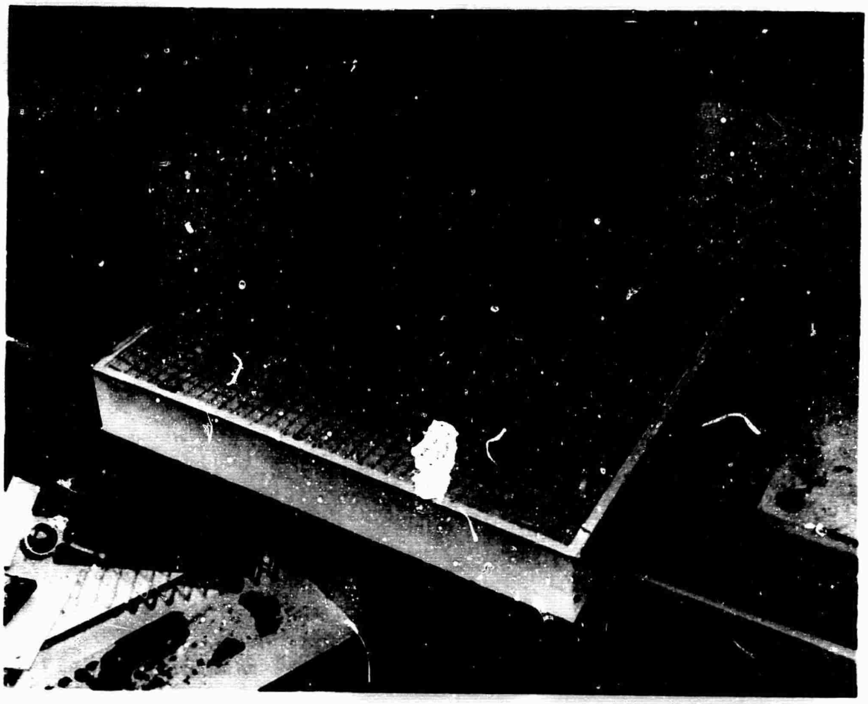


Figure 16. Chemical overlay system tray for experimental overlay patch.

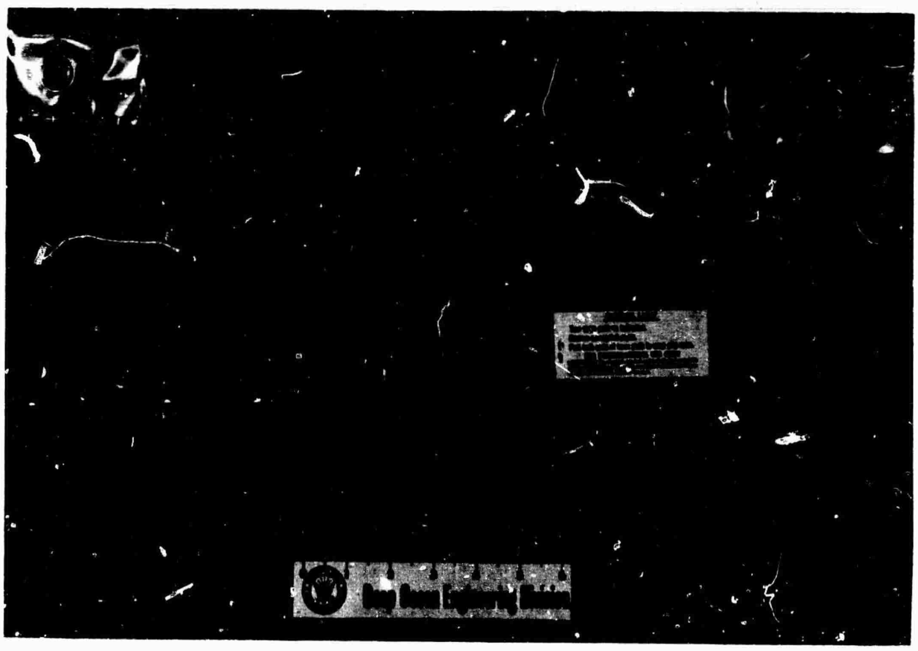


Figure 17. Chemical light packets.

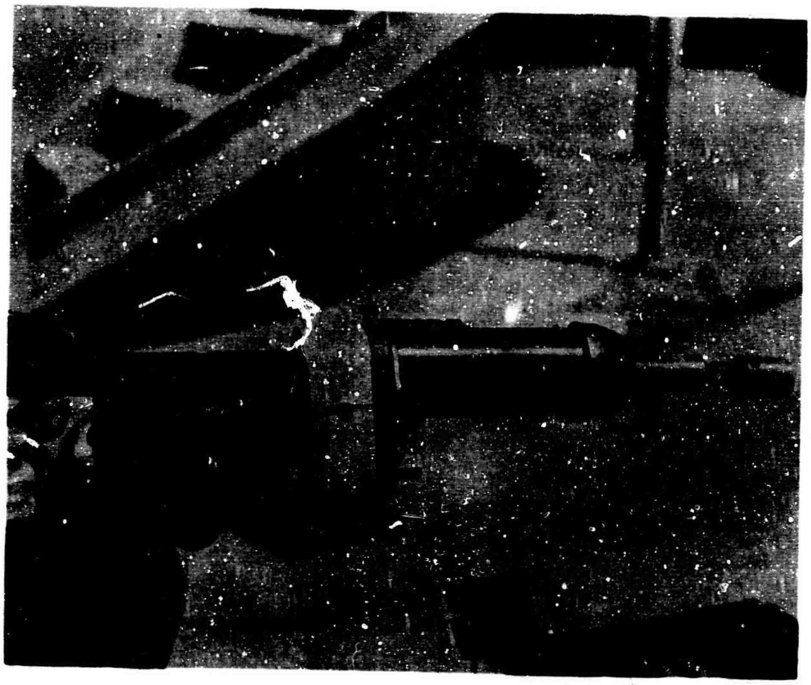


Figure 18. Preprototype electric underwater power tool (impact wrench).

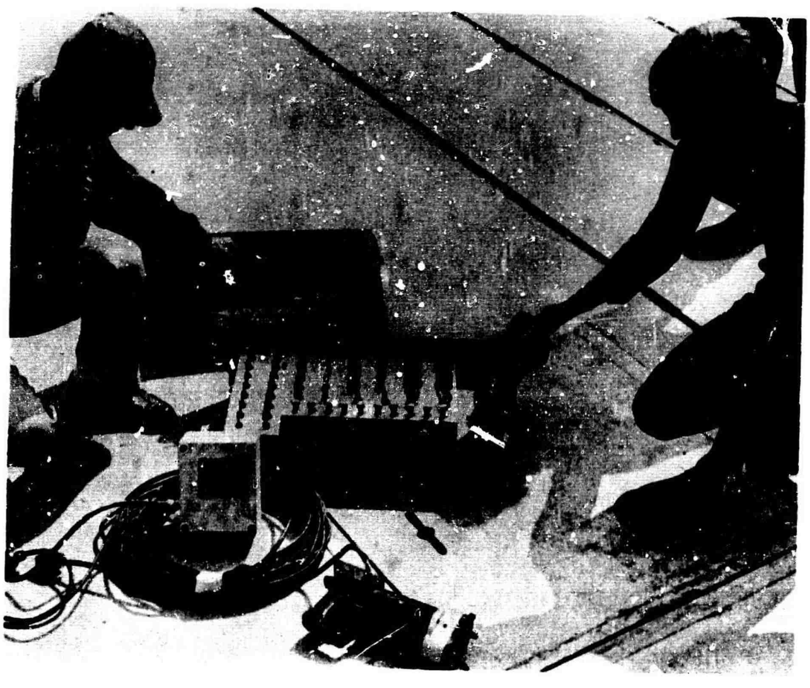


Figure 19. Electric underwater power tool system with accessories.

The tool accessories are housed in a box with a cover which is removed when in use. Magnets mounted at the ends on the back of the box permit quick attachment to a flat, vertical ferrous surface.

Explosively Actuated Cable Cutter

The cable cutter consists of a steel jaw drilled to accommodate a steel cutter piston with a chisel edge, a firing chamber, and a spring-loaded firing pin (Figure 20). It is 9 inches long and about 3 inches wide at the heavy end. The cutter weighs 5 pounds in air and 4 pounds in water. An aluminum safety block (Figure 21) is furnished and is placed between the anvil and cutter piston blade. The safety block is held in place by a torsion spring during storage and shipment. It must also be used when cutting cables of 1/2-inch-diameter or smaller to absorb part of the energy of the cutter piston, to prevent the chisel from shattering on contact with the anvil. The safety block also effectively prevents major damage to the cutter should inadvertent firing occur without a cable in the jaw.

In use, the cutter is so placed that the cable to be cut passes through the jaw. The torsion spring holds the cutter in place on the cable. A lanyard is attached to the firing pin ring. The firing pin is locked with a safety pin attached to a small ring at the side of the firing pin. After the cutter is in place on the cable, the safety pin is removed and the cutter fired by pulling the firing pin ring by means of the lanyard.

Explosively Actuated Stud Driver

The stud driver is a hand held, explosively actuated tool for driving studs into steel plate (Figure 22). It can be used either in air or under water. It is approximately 18 inches long and weighs 17 pounds in air and 15 pounds in water. Externally, it is about 2-1/2 inches in diameter, cylindrical, and about 12 inches long, with a handle at one end and a short flaring cone (spall guard) at the other. The cylindrical portion contains an inner barrel, a body with a firing pin mechanism, and an outer barrel guide. A cartridge, made up of the explosive charge, a piston, and the stud, is loaded into the barrel. The barrel is then screwed into the tool body (Figure 23). When the tool is fired, the explosion drives the piston and stud, in the manner of a bullet through a gun barrel.

When the driver is loaded and ready for use, the barrel protrudes about 3/8-inch beyond the end of the spall guard (Figure 22). In this position, the cartridge primer is beyond the reach of the firing pin so the tool cannot be fired accidentally. The breech end of the barrel is screwed into a splined holder that must be rotated 22-1/2 degrees to align with grooves of a corresponding splined receiver, thus allowing the barrel to be retracted 3/8 inch, permitting the firing pin to reach the cartridge primer. This is accomplished by rotating the knurled barrel guide 22-1/2 degrees against spring tension, with one hand. Because one hand is holding the handle and the other is occupied in rotating the barrel guide, the only way the barrel can be retracted to firing position is by pushing it against the work surface with a force of about 5 pounds.

The driver will fire only if it is positioned approximately at right angles to the work surface, otherwise the tool, pivoting about the edge of the spall guard, will allow the barrel to move forward, moving the cartridge primer out of range of the firing pin. The spall guard, therefore, serves a dual purpose. It protects the user against flying spall and prevents angular firing. Angular firing would increase the chance of ricochet.

When all the above operating conditions have been met, the driver may be fired by squeezing the trigger. The trigger action cocks and then releases the firing pin. The tool may be reloaded under water by replacing the used barrel with another sealed preloaded barrel.

The combination explosive charge, piston, and stud, called the ammunition, is available in various forms for different applications (Figure 24), but the solid stud was the type selected for the SEALAB III tests. It is important to note that the cartridges are designed to penetrate specific plate thicknesses of given materials by varying the powder charge. Typical average extraction forces are indicated in Table 1.

Air-Driven Saw

The saw (Figure 25) is a standard, off-the-shelf, pneumatically driven hacksaw. The principle of operation is by reciprocating pistons. Blade strokes are variable from 0 to 1,100 per minute. Blade stroke is 1-3/4 inches. The saw is designed for use in air, however, the manufacturer and preliminary tests indicate adaptability to underwater use. The tool incorporates complete automatic lubrication of the inner components and blade.

The saw weighs 5-1/2 pounds in air and approximately 5 pounds in water. It utilizes a maximum of 6-1/2 cubic feet of air per minute and operates on air pressures ranging from 80 to 100 psi above ambient. Ordinarily, commercially available high-speed blades are suitable for use with this saw.

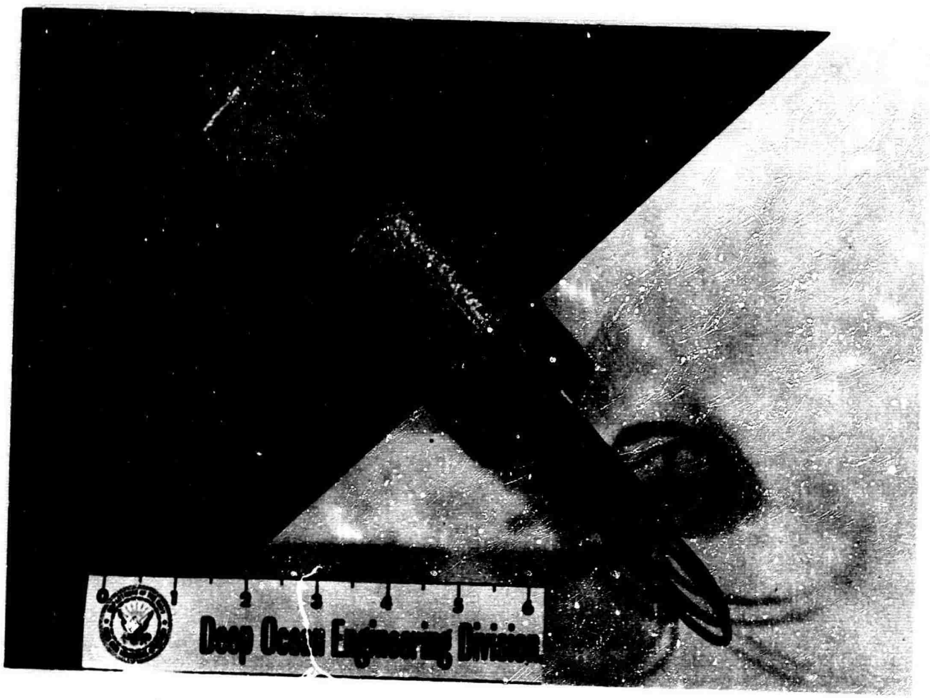


Figure 20. Explosively actuated cable cutter.

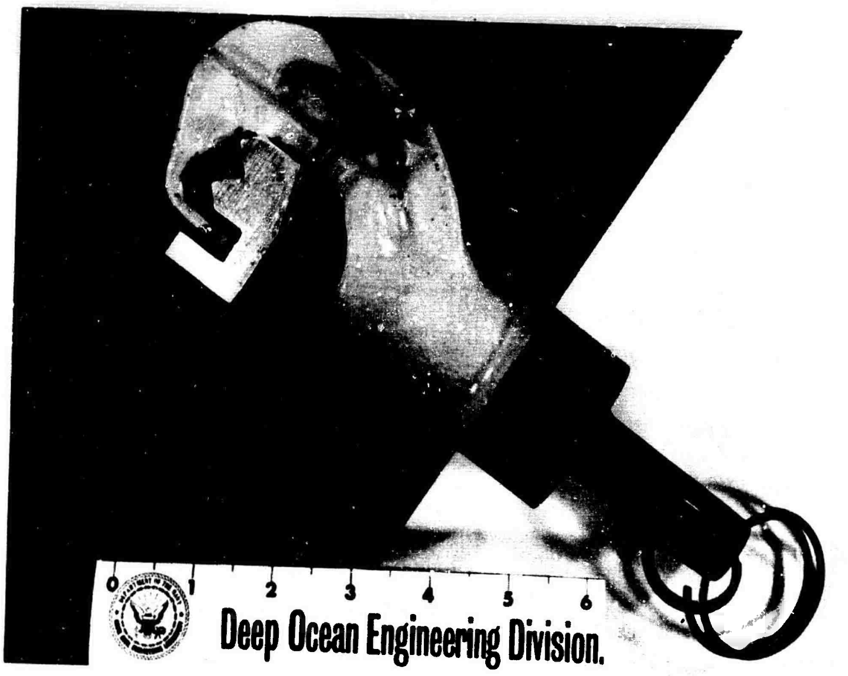


Figure 21. Explosively actuated cable cutter with safety block.

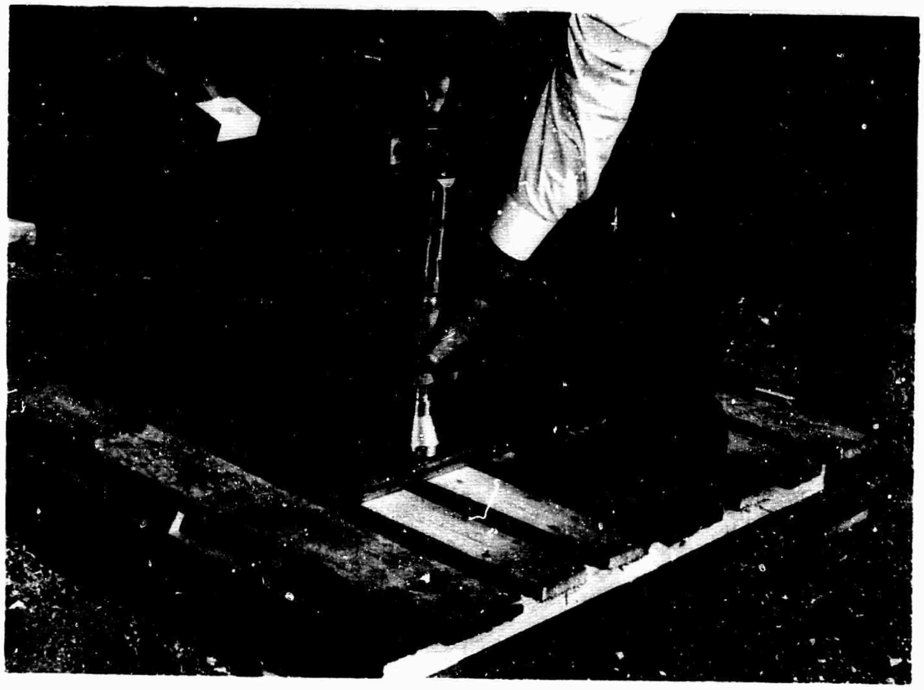


Figure 22. Explosively actuated stud driver.

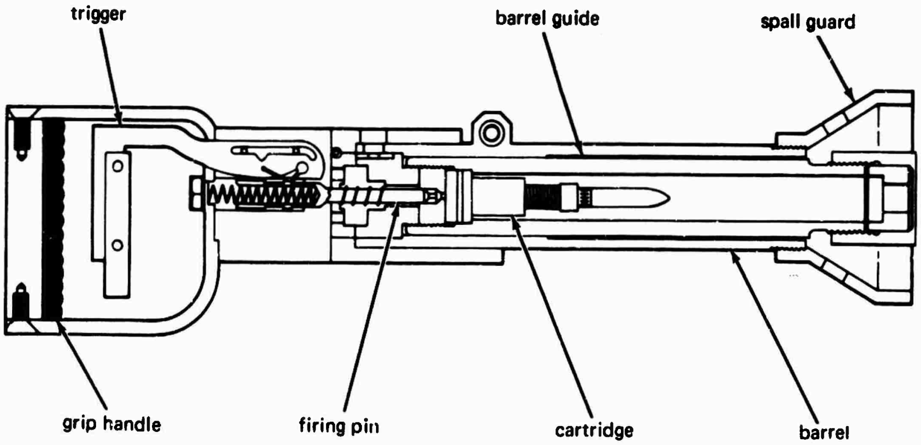


Figure 23. Explosively actuated stud driver, sectional view.

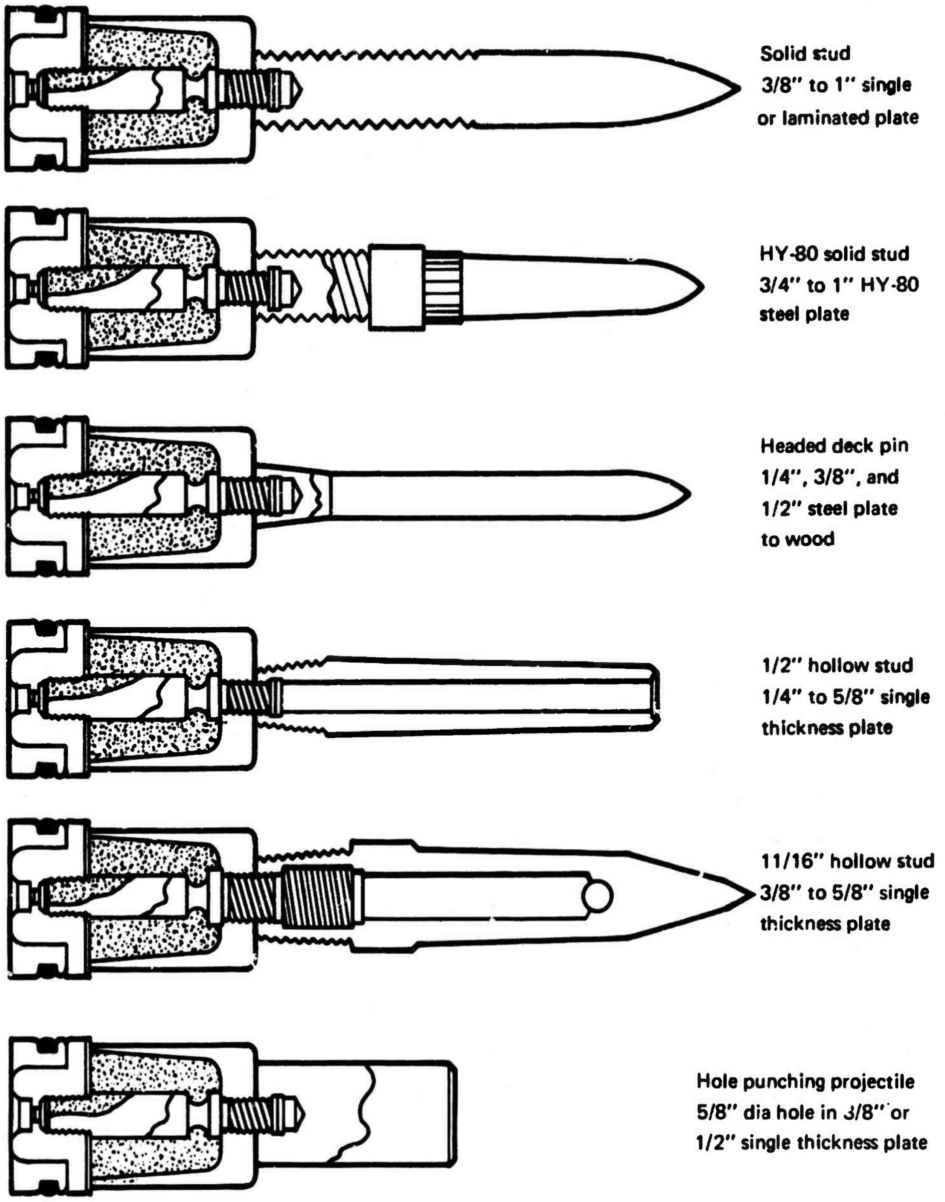


Figure 24. Ammunition for explosively actuated stud driver.

Table 1. Average Stud Extraction Forces

Heavy-Duty Solid Studs in Structural Steel Plate	
Plate Thickness (in.)	Average Extraction Force (lb)
3/8	8,000
1/2	14,000
5/8	16,000
3/4	19,000
7/8	22,000
1	26,000
1-1/8	29,000

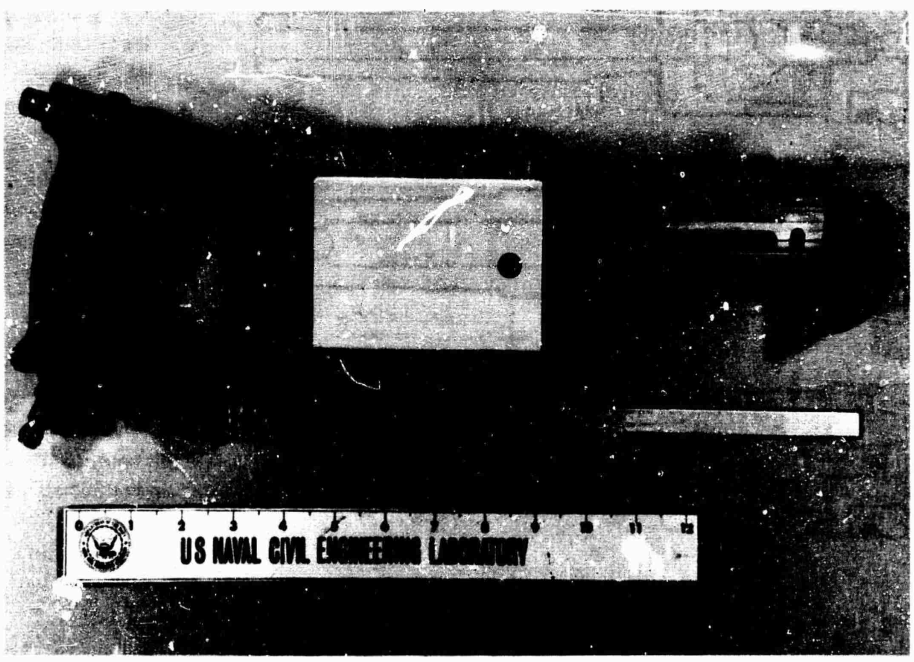


Figure 25. Air-driven saw.

Hand Tools

Standard Tools. The following list of hand tools used in this exercise are standard items (Figure 26) familiar to all mechanics and need no description other than the names:

Pipe wrench, 14-inch
Crescent wrench, 14-inch, 10-inch
Screwdrivers, standard 6-inch, Phillips, allen
Socket wrench with ratchet
Box end wrench, 1-1/2-inch, 1-1/8-inch, 15/16-inch, 3/4-inch
Open end wrench, 1-1/2-inch, 1-1/8-inch, 15/16-inch, 3/4-inch

Special Hand Tools. Special hand tools used in the exercise are as follows:

1. Screwdriver with ratchet-palm-grip handle. This is similar to a common screwdriver with either a standard or Phillips blade. A flat palm-grip (Figure 27) similar to a handwheel, 3 inches in diameter with a ratcheted 3/8-inch-square drive shank, is provided. The shank fits into a 13/32-inch-square socket in the end of the screwdriver handle. The palm-grip is said to multiply turning power four times and provides for a comfortable grip. The ratchet adjusts to forward, reverse, or locked positions.

2. Selective-socket driver with palm-grip handle. This tool is similar to the socket-end screwdriver described above and uses the same square drive palm-grip. The tool end consists of a series of concentric hexagonal tubes (Figure 27). The outboard tube is rigidly attached to the shaft while the inboard tubes are spring loaded and when at rest are flush with the end of the exterior tube. The nest of tubes is pushed onto a bolt head or nut which, when properly aligned, depresses all tubes smaller than the nut. The tubes that encase the nut become the socket for turning it. Each tool accommodates four nut sizes. Several tool sizes are available.

3. Socket driver with palm-grip handle. The socket with palm-grip is similar to the screwdriver with palm-grip handle described above except that it utilizes a 7/16-inch socket (Figure 27) instead of a screwdriver blade.

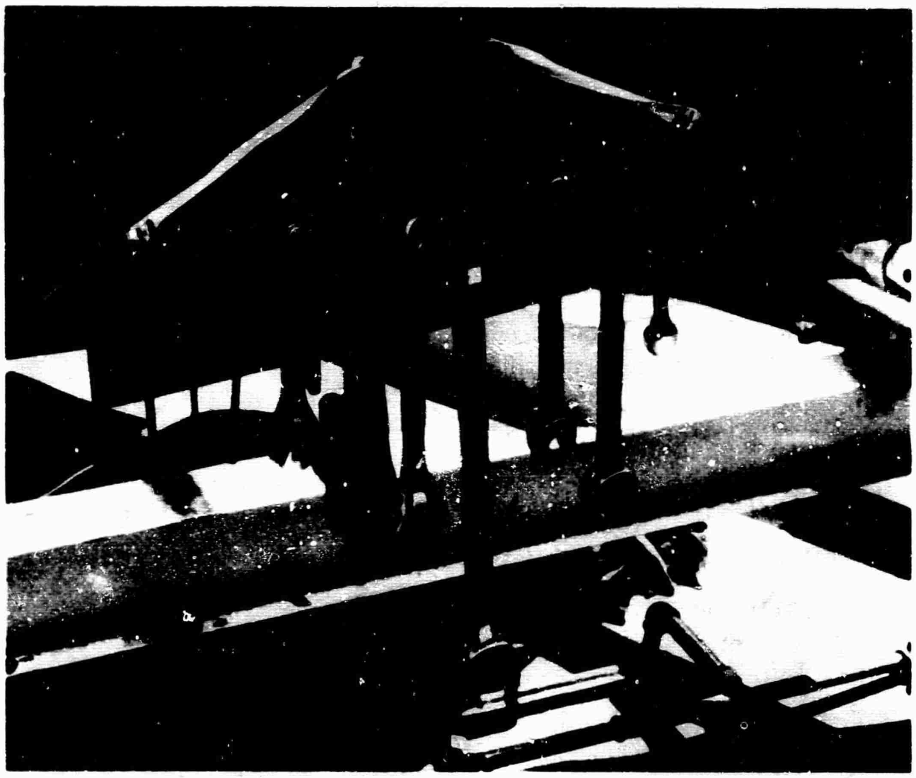


Figure 26. Standard-type hand tools.

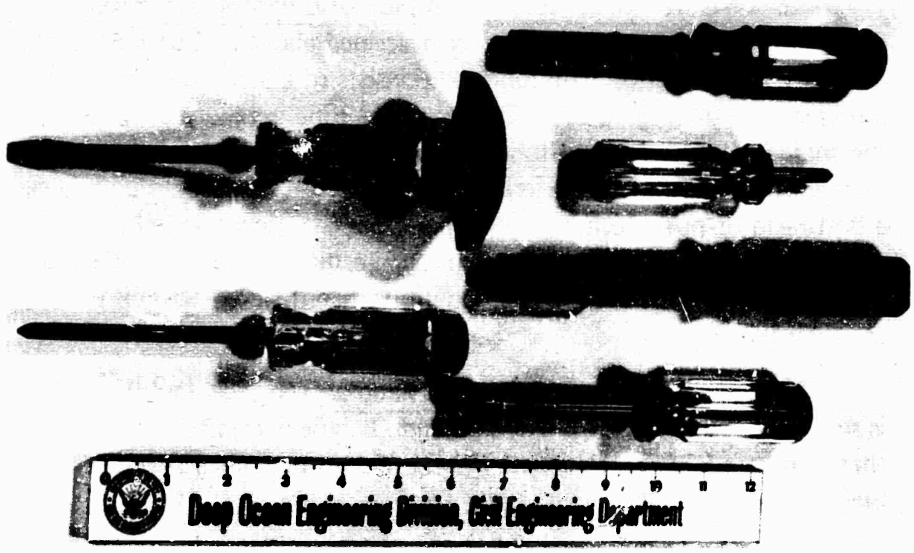


Figure 27. Special hand tools.

Tool Test Stand

To accommodate evaluation testing of the several unique tools developed for construction and salvage operations at deep depths, it was determined that a special test-bed (tool test stand) (Figures 28 and 29) for mounting all appropriate surfaces and objects on which tests were to be performed would best serve the purpose. Certain test-bed design criteria were established.

As required by the test-bed design criteria, two identical groupings of test surfaces and objects are installed on vertically oriented faces of backing plates. Plate orientation can be accomplished on sea floor slopes as great as 15 degrees. The working height of these surfaces is such that divers can accomplish part of the testing while standing on the sea floor, yet some must be completed while the diver is denied the stabilizing effect of support from the sea floor. Booms are provided for mounting lighting and television cameras for coverage of each backing plate during testing.

The tool test stand serves as a vehicle for mounting and transporting equipment required for the bottom stabilization experiments (Figures 15 and 16) and incorporates bins for stowage purposes. Hand tools for tests will be transported in these bins. The HY-80 steel test plate for the 25-ton lift capability padeye is mounted on the stand. The stand has a dry weight of approximately 6,500 pounds and an in-water weight of about 5,000 pounds. The tripod form provides for stability on the sea floor in the event that the floor is uneven. A low center of gravity and weight balancing provide stability during lowering operations.

Vertical and horizontal orientation of the backing plates is accomplished by suspending each plate from a boom arm, by a ball-joint swivel at midpoint on the top edge, and providing two adjustment arms, also on ball-joint swivels, which may be locked in position when proper backing plate orientation is established. Locking is accomplished by a setscrew with hand knob. Since the plate weight is carried by the top mounting, orientation is accomplished with little effort on the part of the diver.

Discussions with project managers for the various salvage equipment developments established that 4- by 6-foot backing plates 1/2-inch thick would provide sufficient work area for contemplated evaluation tests. One plate was suspended from each of two sides of the tripod frame. Each backing plate is provided with rows of eyebolts down each outer edge and down the center. Tethering straps with snap rings are provided to attach to the eyebolts to hold the diver to the workpiece. The diver can adjust his position by selecting different eyebolt attachment positions. He may also shift the position of the strap in relation to his body to gain maximum mechanical advantage. Each backing plate is also provided with two shelves to be utilized when a requirement exists.

The camera and light booms are adjustable in length by adding extra sections provided and in height by raising, lowering, or rotating their T-section mounting. The camera angle is adjustable through a double ball-joint swivel mounting. These ball joints can be locked by tightening down on the ball clamp.

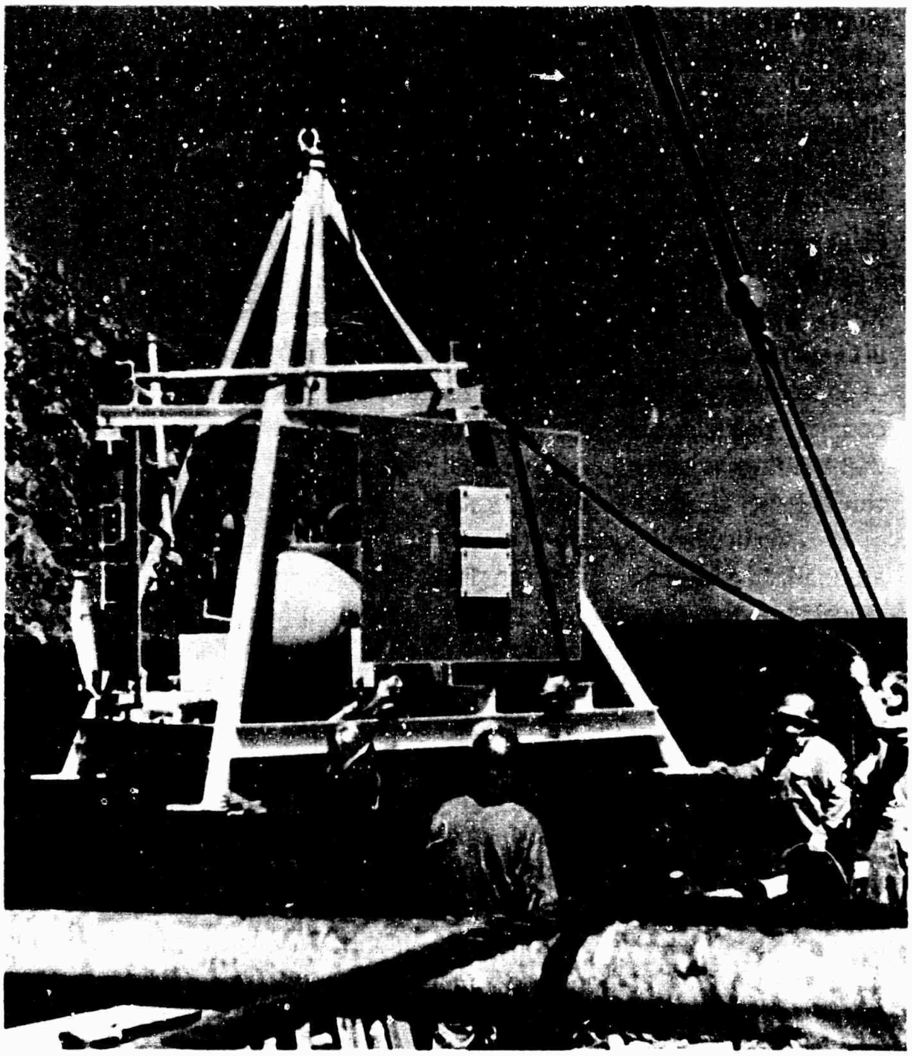


Figure 28. Tool test stand.

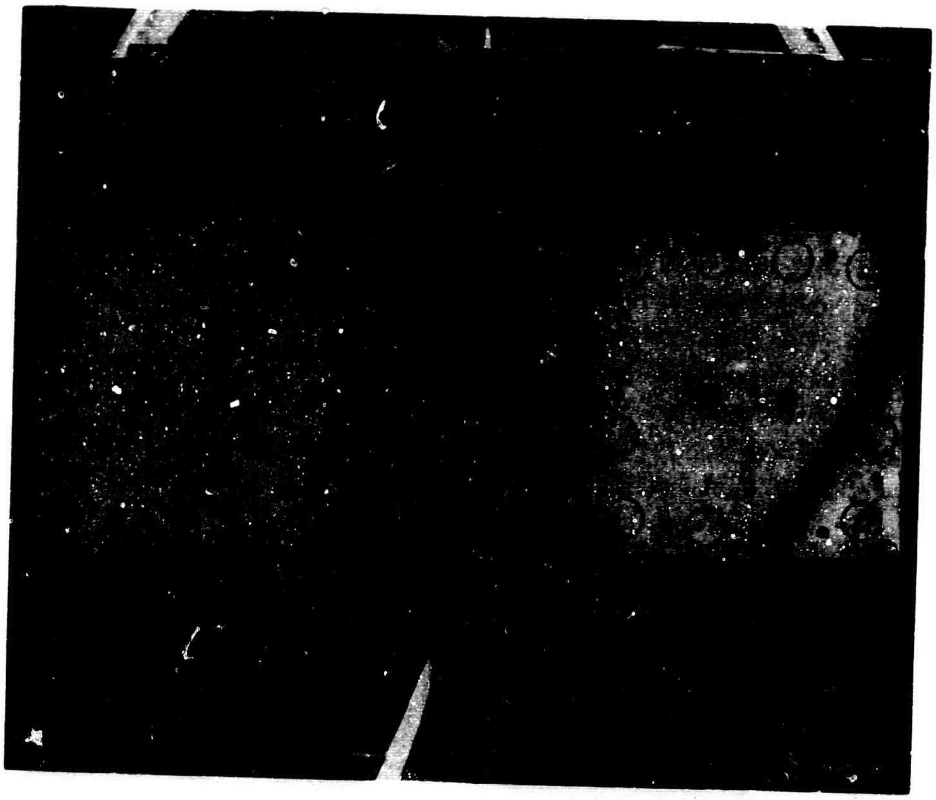


Figure 29. Tool test plates.

SERVICES, FACILITIES, AND TEST EQUIPMENT LOGISTIC SUPPORT

The Supervisor of Salvage, USN, in pursuing the program for enhancing salvage capabilities, has acquired the services and technical abilities, of numerous activities for carrying out the development phases of various equipments. The equipments selected as appropriate subjects for the Salvage Lift Systems Test and Underwater Tools Tasks required considerable logistics support by the cognizant activities. The contributing activities and the support to have been provided by each are set forth in Appendix D.

DISCUSSION

Following the initial designation of the equipments to be included in the projects sponsored by the Supervisor of Salvage, USN, and the subsequent proposals for demonstrating and evaluating the equipments, a plan was evolved for accomplishing the necessary diver indoctrination and training.

As the prototype test equipments became available, they were shipped to the Naval Civil Engineering Laboratory (NCEL) which had been assigned responsibility for coordinating the effort under the direction of the Supervisor of Salvage, West Coast Representative. Divers (Figure 30) assigned by the Ocean Engineering Branch, Deep Submergence System Project (DSSP), reported to NCEL for indoctrination and preliminary training with the devices ashore.

At the time of the planning phases for the entire SEALAB effort, one of the goals established was a study of the effects of deep sea environment upon the diver's capabilities. Planning was, therefore, initiated for conducting intensive human engineering studies in conjunction with other scientific studies. These studies became an integral part of the salvage projects to be included. The Engineering Psychology Division, Office of Naval Research (ONR), was assigned overall coordination of this facet of the project. The Human Factors Engineering Branch, Naval Missile Center (NMC), Point Mugu, was selected to provide personnel to conduct these studies for the salvage projects. Aiding in this effort were personnel from the University of California at Los Angeles (UCLA).

Initial efforts in indoctrination and training with the salvage work projects were conducted in January 1968. This training concerned itself with diver familiarization with the equipments in classroom and laboratory situations. Personnel associated with the development of the equipments acted as instructors and demonstrated both the assembly of the equipments from their component parts and the proper or recommended operation. Instruction was presented in safe handling and proposed handling techniques. Divers were then given guided instruction as they assembled and operated or simulated operation of the equipments. The indoctrination program was then moved to the Point Mugu Naval Missile Center surface tank (Figure 31), where instructors were able to observe the divers operating the equipments underwater and thus, make additional pertinent instructional comments.

Personnel from the Human Factors Engineering Branch, Naval Missile Center, Point Mugu, and from the Bioengineering Technology Laboratory and the Performance Physiology Laboratory, UCLA, participated in these and all following training phases. Familiarization with the functions and operation of the equipments facilitated the development of human physiological performance data collection criteria and techniques and the assessment of human factors engineering aspects associated with interfacing divers and equipments (Appendix B). Initial planning considered establishing baseline performance data for untrained as well as trained divers in operating equipments in air, surface tank, and shallow water (50-foot-depth) exercises. These data were then to be compared with data collected at the SEALAB III depth—600 + feet. Exercises at the 50-foot-depth were planned to be conducted under as nearly identical conditions as possible to those expected at SEALAB III, with the exceptions that dives would be made from aboard ship rather than from an underwater habitat and that the ambient water temperature and pressure would reflect operations at the shallow depth.

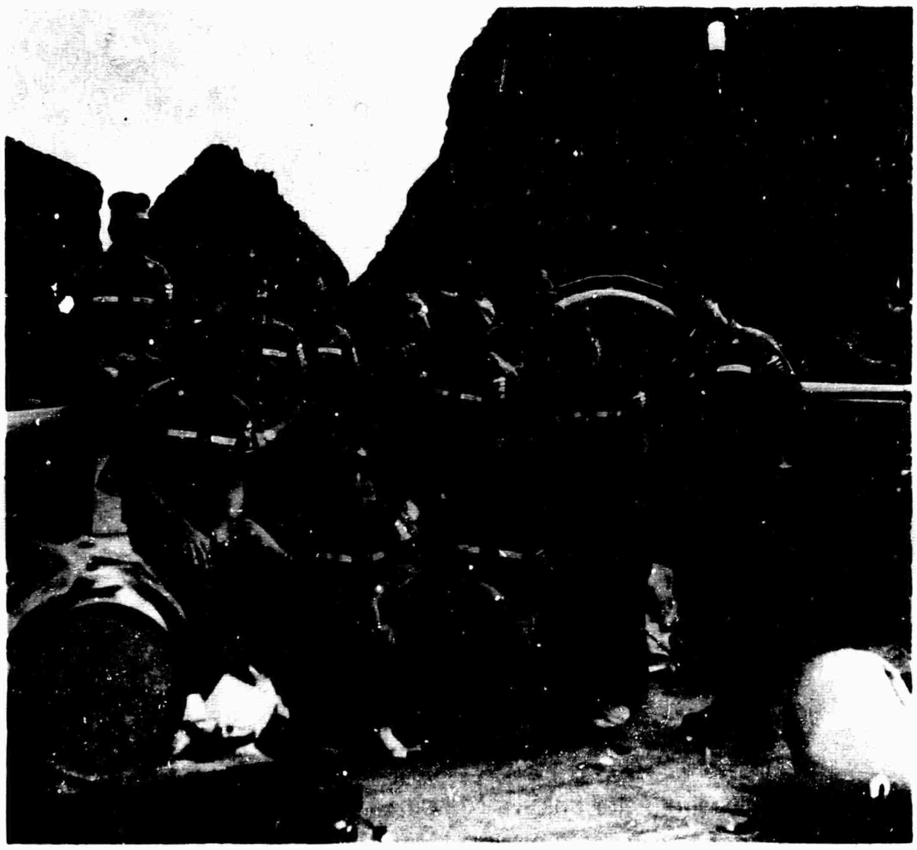


Figure 30. SEALAB III, Team Two divers.

As diver training with equipments progressed, it became evident that similarity of conditions between successive training periods would become increasingly difficult to achieve; at least until the final training to be conducted prior to the actual SEALAB III exercise. This was because early training revealed the necessity, in many instances, for equipment modifications and changes in operational techniques before training in the succeeding phase could be undertaken. A second reason was that certain equipments were not continuously available. Some of these instances are discussed in a later section of test results.

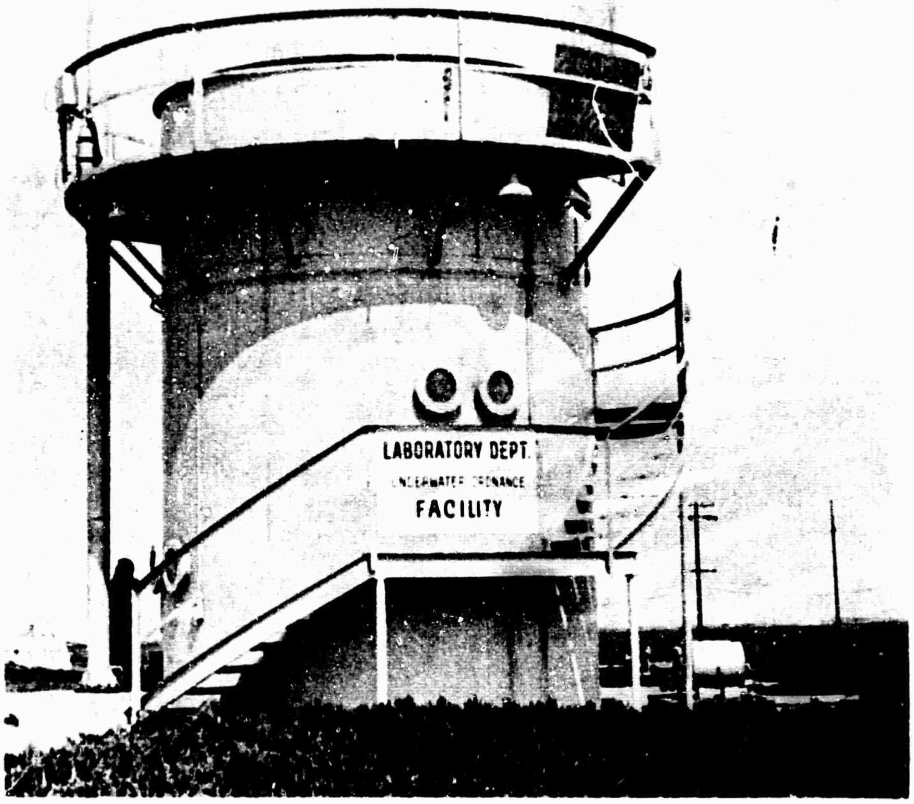


Figure 31. Surface test tank.

The second major phase of training was conducted in 50-foot-deep water off Anacapa Island from aboard the USNS ***GEAR*** (ARS-34) in May 1968. Because of other training commitments for some diver's life support equipment and delayed contractor delivery of others, this training was conducted by divers outfitted with conventional scuba diving gear. These efforts were monitored by closed-circuit TV and covered by still photographs.

The third major phase of training was also conducted at the Anacapa Island site from aboard the USNS ***GEAR*** in August 1968. Aquanauts were provided Diving Unlimited open-circuit water-heated suits (Figure 32), a mixed-gas breathing medium (helium-oxygen) from a shipboard mounted bottled supply, Mark VIII breathing system backpacks, clamshell helmets, and a prototype surface-ship-mounted diver's open-circuit water heating system. These diver life support equipments provided a good measure of similarity to proposed conditions at SEALAB III. The water heater provided the same water temperature and flow to the divers that the York-Shipley system to be used in SEALAB III would provide. Incidental to the exercising of the life support equipments planned for or simulating those planned for use in SEALAB III, a band mask (Figure 33) was tested for comment by aquanauts. The other diver equipments used in training were planned for use in SEALAB III. Communication between divers and habitat was the principal item not available to the extent proposed for SEALAB III. A two-way voice circuit to one member of the team was supplemented by diver's hand signals via the TV monitor. Video taping with instant playback capability proved to be an asset in providing post-dive instruction and critique.

To prevent inadvertent load lifting and ascent by the inflatable pontoons, a concrete clump of considerable weight was placed on the sea floor at the site. Since use of the pontoons and collapsible lift devices at SEALAB III was to be for demonstration of feasibility only and not for actual salvage, the overweight clump served as a safety factor. No uncontrolled lifts were made where some accident could have caused a load to be dumped onto divers operating below. No such lifts were planned for SEALAB III for the obvious reason of safety for personnel and equipment below. The weight to have been used at SEALAB III is described with equipment to be supplied by NCEL in Appendix D. The weight has been prepositioned at the San Clemente Island (SEALAB) site.

The tool test stand was used in the Anacapa Island training exercises and, as a result, a number of modifications were made at the request of participating divers and at the suggestion of the human factors studies personnel.

Upon initiation of salvage tests, divers would proceed to the tool test stand and orient the backing plates on which all test plates, etc, will have previously been mounted. With these plates in position and locked, the divers will extend the camera booms by adding the additional sections. These sections are mounted in brackets atop the hinged booms and are provided with guide sleeves and threading for easy assembly.

The light and TV camera T-section is mounted and locked against the hinged boom section when the stand is lowered. When the extensions have been added, the T-section can be unlocked and moved to any point along the boom length. Upon completion of the salvage tests, the T-section would be moved to its original position on the hinged boom section and locked into place. The extension sections will be removed and stowed in their brackets. The hinged sections will be rotated and lashed to the tripod leg in its shipping mode. The stand will then be ready for retrieval.

Figure 32. Diving Unlimited open-circuit hot water-heated suit.

SAFETY PRECAUTIONS

Safety precautions listed herein must be regarded as incomplete because of the experimental nature of the equipment. Due care has been exercised in determining applicable safety precautions, but past experience indicates that formulation of a complete set of safety precautions is impossible until considerable field use, including accidents, has been experienced. Policy, therefore, strongly recommends that all aquanauts and all support personnel not only observe all safety precautions, but also proceed with due care, always keeping in mind the experimental nature of the equipment. If there was any doubt about the relative safety of any of the tests or test equipment, these tests would not have been included in SEALAB III. On the other hand, however, if it was definitely known there were no hazards involved, safety procedures would not be required.

Figure 33. Aquanaut wearing band mask.

Precautionary measures taken to minimize danger to the divers included designing all load carrying components to a minimum of 1.5 times their rated capability and proof testing all sealed hollow components to a minimum 1.5 times expected pressures, either external or internal. Electrical equipments were required to pass specified electrical certification procedures.

General Precautions

1. All hands are cautioned to be particularly careful to observe all safety precautions in the rigging and handling of equipment topside to avoid dropping anything that may endanger the divers below.

2. All personnel on surface ships or boats, especially visitors, are warned <u>not to throw anything over the side.</u> (Hard items may hit the divers and food may attract sharks.)

3. Divers are not permitted directly over or under any of the pontoons while the pontoons are inflated or being inflated or deflated.

4. Divers are to move into or under the habitat while any equipment is being lowered or raised by the surface ship (USNS ***GEAR***).

5. All hands must beware of becoming entangled in rigging. Divers must be especially cautious concerning rigging attached to any lift device.

6. IMPORTANT: Diver umbilicals must remain well clear at all times.

7. In planning diving operations, job scheduling should not require maximum physical exertion by divers. In addition, divers shall be warned to avoid maximum physical exertion at all times possible. This is because reserve strength can be expended in a very short time under water. To expend this reserve strength would seriously reduce response time available in the event of a serious emergency.

8. All rigging is required to pass a safety certification test and rigid hollow equipment is required to pass a collapse pressure test equal to 1.5 times the exercise depth. Inflatable items are required to have automatic pressure relief devices.

9. Large lift devices are not to be shackled to the small padeyes on the load clump identified for restricted use (Figure 34).

10. Divers must be aware of the possible effects of metal test devices on diver's compass readings.

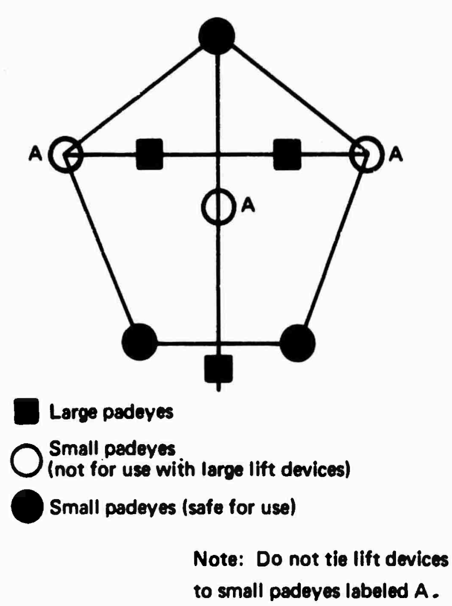


Figure 34. Schematic top view of load clump.

Precautions Specific to Equipments

1. Hunley-Wischhoefer System

a. Topside precautions.

(1) On the buoy-fairing assembly, be sure the safety latch locking device is securely fastened. If this item fails, the buoy could become detached from the fairing assembly and drop the fairing and all its gear on the divers below.

(2) Surface vessels should not be moored directly over the salvage pontoon during inflation; all lines should be of adequate length to permit moving a safe distance to one side.

b. Diver precautions.

(1) Use only the small valve to flood the toroidal ballast tank at depth.

(2) When releasing the buoy-fairing assembly to permit it to float to the surface, grasp only the release handles and pull them clear. (If any other part of the device is grasped, it could quickly pull the diver above his safe depth.)

(3) Notify topside before releasing the buoy-fairing assembly to assure that no diver or boat at the surface will be endangered.

(4) If a lead weight is removed from the dragskirt to permit attainment of neutral buoyancy, it must be replaced prior to releasing the buoy-fairing assembly to surface.

2. Twenty-Five-Ton Lift Padeye

a. Topside precautions.

(1) Handle with care to assure that the stud-driving assemblies are neither damaged nor fired prematurely.

(2) Ensure that safety pins are in place and that firing lanyards are attached.

(3) Studs shall be loaded into the barrels <u>in air</u>, by qualified Naval Ordnance Laboratory (NOL)/Mine Safety Appliances (MSA) personnel only.

(4) Misfired stud cartridges should be disposed of through proper explosive ordnance disposal means.

b. Diver precautions.

(1) Keep fingers clear of the underside of the padeye when approaching flat ferrous metal surfaces (i.e., the stud embedment test plate) due to the attraction between such surfaces and the magnets used to hold the padeye in place prior to firing the studs.

(2) Pull only one safety pin at a time.

(3) Use lanyards when firing the studs. Fire only one stud at a time.

(4) In case of a misfire, wait about 30 seconds, unscrew the firing mechanism, recock, replace, and fire again; repeat a second time. If it still does not fire, proceed with the other barrels. Mark the unfired barrel by wrapping the firing lanyard around it. Notify topside that the marked barrel has misfired.

(5) Divers must avoid being in line with the barrels when firing.

3. Collapsible Salvage Pontoon (8.4-Ton)

a. Topside precautions.

(1) Surface vessels shall not be moved directly over the salvage pontoon during inflation or while inflated; all lines should be of adequate length to permit surface vessel movement as required.

b. Diver precautions.

(1) Experience has shown that the collapsible pontoon can be hazardous in all phases of the test operation, particularly in the late stages of pontoon inflation, when the pontoon is in motion (as when it rises to the surface), or when floating on the surface. Also, rigging may fail or the pontoon may rupture and lose its buoyant lift capacity so that the pontoon will return to the bottom. Divers should not be over or under the pontoon or within 15 feet of the pontoon's side after inflation is underway.

4. Chemical Overlay

a. Topside precautions.

(1) Ensure that all valves are OFF.

(2) Do not alter valve settings.

b. Diver precautions.

(1) After working with the chemicals, divers are to check each other carefully before entering either the habitat or personnel transfer capsule (PTC) to ensure that no chemical adheres to them that may be carried into these areas.

(2) If any chemical adheres to a diver, it must be scraped off.

(3) Check for current direction relative to the "test patch" before and while using the stabilization equipment. Current direction must be away from the habitat, PTC, and divers.

(4) Hold applicator over the "test patch" while discharging.

(5) <u>IMPORTANT:</u> Open the air vent to discharge air pressure upon completion of the test.

(6) Return the applicator to its stowage bag upon completion of testing.

5. Chemical Lights

a. Topside precautions.

(1) Ensure that all devices are intact.

b. Diver precautions.

(1) Perform this exercise down-current from the habitat.

(2) Do not take lights into the habitat.

(3) In the event of chemical leakage, prevent contact with the skin.

(4) Return used light packages to their transfer cage on the test stand.

6. Variable Buoyancy System (200-Pound Lift)

a. Topside precautions.

(1) Hydrazine fuel is a corrosive liquid with toxic vapors and shall be handled in accordance with safety precautions similar to those for handling aviation gasoline. Fuel fires can be extinguished with water and foam fire-fighting systems may also be used.

(2) The fuel shall be handled by qualified Naval Weapons Center (NWC) or NCEL personnel only.

(3) All unnecessary personnel shall be evacuated from the immediate vicinity while the fuel is being handled.

(4) No smoking or open flames shall be permitted on board while the hydrazine fuel is being handled.

(5) A fire hose shall be available for immediate use at the fuel handling site.

(6) Any spilled fuel shall be washed away immediately.

b. Diver precautions.

(1) Before inflating or deflating the variable buoyancy system, be sure that the current will not carry the gases toward the habitat or the PTC.

(2) Do not attempt to hold the lift device if a load breaks loose. (Although the device is small, it could quickly carry the diver above his safe depth.)

(3) To decrease the lifting force of the device in a threatened emergency, move the zipper slide quickly to the top of the unit.

(4) Be sure that the umbilicals are well clear at all times.

7. Two-Ton Lift Pontoon

a. Topside precautions.

(1) Hydrazine fuel is a corrosive liquid with toxic vapors and shall be handled in accordance with safety precautions similar to those for handling aviation gasoline. Fuel fires can be extinguished with water and foam fire fighting systems may also be used.

(2) The fuel shall be handled by qualified NWC/NCEL personnel only.

(3) All unnecessary personnel shall be evacuated from the immediate vicinity while the fuel is being handled.

(4) No smoking or open flames shall be permitted on board while the hydrazine fuel is being handled.

(5) A fire hose shall be ready for immediate use at the fuel handling site.

(6) Any spilled fuel shall be washed away immediately.

b. Diver precautions.

(1) Before inflating or deflating the pontoon, be sure that the current will not carry the gases toward the habitat or the PTC.

(2) Divers shall never be directly above or below the 2-ton pontoon while it is inflated or being inflated.

(3) IMPORTANT: Keep the umbilicals well clear at all times.

8. Explosively Actuated Stud Driver

a. Topside precautions.

(1) Explosive studs shall be loaded, in air, by qualified NOL/MSA personnel only.

(2) Ensure protection of machine threading on the barrels.

(3) Misfired stud cartridges shall be disposed of through proper explosive ordnance disposal means.

b. Diver precautions.

(1) At no time during stud firing will any person allow part of his body to extend beyond the plane of the test plate. There is a natural tendency to put an arm around the test plate to hold on. Avoid this.

(2) If a cartridge fails to fire when the trigger is pulled, keep the stud driver in position against the work plate. Release the trigger and pull again. If it still does not fire, keep in position against work plate for 30 seconds after the last trigger pull as a safeguard against the possibility of a delayed discharge; then remove and replace the barrel. Use due caution in pointing the loaded misfired barrel.

(3) When handling the loaded driver, the diver shall keep it pointed down and away from other personnel and only raise it to position on the test plate after the other diver or divers are well clear. It shall be treated as a hand gun—namely, "it is loaded and dangerous at all times."

(4) IMPORTANT: Keep umbilicals clear at all times.

9. Explosively Actuated Cable Cutter

a. Topside precautions.

(1) Do not remove the safety block from the cable cutter jaw.

(2) Carry the cutter by the carrying loop on the torsion spring. Do not carry it by the jaw, safety pin ring, or firing pin ring.

b. Diver precautions.

(1) Do not remove the safety block from the cable cutter jaw until ready to use the cutter.

(2) If a cable cutter fails to remain in position on the cable by itself, it can be fired safely while holding the cutter in position with one hand and pulling the firing lanyard with the other. Do not attempt this method without first obtaining permission from topside (Supervisor of Salvage (SUPSALV) representative).

(3) IMPORTANT: Keep the umbilicals clear at all times.

(4) Keep well back from the cable to be cut while exercising this tool. Be cautious of the wire strands when they unlay after the cable is cut.

(5) No attempt shall be made to disassemble the cutter.

(6) Carry the cutter by the carrying loop on the torsion spring. Do not carry it by the jaw, the safety pin ring, or the firing pin ring.

(7) Do not pull the safety pin until the cable cutter is placed in position ready to fire.

(8) Hold the cutter with one hand and withdraw the safety pin with the other.

(9) Be sure the cutter is perpendicular to the cable and that the cable is resting against the anvil.

(10) If a cutter fails to fire, wait 30 seconds. Remove it from the cable, holding it by its shank only, and place it in a tool bin on the stand.

10. Electric Underwater Power Tool

a. Topside precautions.

(1) Ensure that the electrical power cable is undamaged.

(2) Ensure that the dummy connector is installed on the electrical power cord connector.

b. Habitat personnel safety precautions.

(1) A safety circuit is an essential part of the tool system. This circuit must be checked out before the tool power cord is plugged into the power supply. To check the circuit:

(a) Remove the Plexiglas inspection plate from the circuit box and set the circuit breaker to ON.

(b) Test the safety circuit by depressing the small red button. (Circuit breaker should snap to OFF.)

(c) Reset circuit breaker to ON. Replace the Plexiglas cover.

If the safety circuit does not function properly, the exercise shall not be continued until the safety circuit is either replaced or repaired.

(2) The tool power cord must be plugged into the safety circuit box only.

(3) Recheck the circuit breaker to ensure that it is still set to ON.

c. Diver precautions.

(1) Keep umbilicals well clear of test work and of the tool power cord.

(2) Keep hands well clear of the "working end" of the power tool.

11. Air-Driven Saw

a. Topside precautions.

(1) Ensure that the lubricating oil vial is filled.

b. Diver precautions.

(1) Umbilicals must be clear at all times.

(2) Hands must be well clear of the "cut" area of the test plate and the moving blade.

(3) The saw is not to be operated except when sawing the test plate.

12. Hand Tools

a. IMPORTANT: Keep umbilical well clear at all times.

ADVANCE PREPARATION OF EQUIPMENT

All available equipment had been staged at NCEL. Prior to the shallow-water-training test day, all equipment was loaded on the USNS *GEAR* for transportation to the Anacapa Island test site. The following preliminary preparations were performed after arrival on site:

1. Installed a Roylyn 1-1/4-inch quick-disconnect coupling on the pontoon end of the 800-foot, 1-1/4-inch air hose.

2. Connected the topside end of the air hose to the air manifold on the USNS ***GEAR***. This manifold had a shutoff valve and a vent valve in the line to the air hose, and a 0 to 500 psi range air pressure gage.

3. On the 8.4-ton salvage pontoon, torque of the capscrews connecting the relief valves and end plates to the pontoon carcass were checked. The torque values of screws (items 1 and 9, Figure 5) were set to limits of 96 lb-in. and 360 lb-in., respectively.

4. The 1-1/4-inch air hose was coupled to the salvage pontoon, checked to ensure that it was securely connected, and the air valve on the pontoon connection then was opened.

5. Divers confirmed the location of the previously placed 30-ton load clump.

6. The tool test stand was rigged and lowered by the USNS ***GEAR*** to a position determined by the divers, adjacent to the load clump, suitable for TV and still-camera coverage. (For SEALAB III, divers would mount lights on the appropriate boom of the tool test stand for coverage of the test in progress.)

7. The 1-1/4-inch air hose (800 feet for SEALAB III) was rigged for the 8.4-ton pontoon by lashing 4-foot pendants of 6- or 9-thread line with clove hitches at 50-foot intervals along the air hose. (The pontoon was lowered on a 3-inch-circumference polypropylene line and the air hose was paid out with it. The 4-foot pendants were lashed to the lowering line with a rolling hitch in such a manner that, when the system was retrieved, the free end of the pendant could be jerked to undo the lashing.)

8. For SEALAB III, the safety circuit for the electric underwater power tool would have been mounted in the habitat prior to lowering the habitat. In the shallow-water tests, the safety circuit was aboard the USNS ***GEAR***.

9. Explosively actuated equipment projectiles were loaded into the barrels.

10. The Hunley-Wischhoefer system was assembled.

11. Hydrazine lift systems were fueled.

12. A prototype (Clayton) diver's hot-water heating system was provided on the USNS ***GEAR*** for use with open-circuit Diving Unlimited wet suits.

13. A bank of mixed gas bottles was provided on deck for use with the Mark VIII breathing apparatus and clamshell helmets.

DIVER WORK SCHEDULES

Preliminary conferences were held at which the amount of work to be required of the divers during each dive was determined, the time span of each dive having previously been established. A logical division of the sequence of events for each test was established and daily "packages" of scheduled work were set.

For SEALAB III, each package was to be assigned a designator from the International Phonetic Alphabet. However, the packages would not necessarily follow in the order of their alphabetical sequence. For example, day Alpha need not be first, nor will day Bravo necessarily have to follow Alpha. Just before the operation, a proposed schedule would be laid out in which each calendar day would be designated by one of the phonetic letters to indicate the prime work schedule for that day. In addition, a second alphabetical designation would be assigned to indicate an alternative work plan for that day. This system has been designed to prevent work stoppage on the bottom due to a malfunction of equipment. These daily schedules, in step-by-step procedures, are provided as Appendix C.

RESULTS

Results obtained from the various test phases were interdependent upon several influential factors, and it should be stressed that all test equipments were not continuously available for training purposes. This was because many of the devices could be considered as prototypes and were not completed in the same time frame. Many of them required modifications based upon test results and, generally, these modifications required return of the equipment to the cognizant agencies. This necessitated additional familiarization and retraining where modifications were significant. During the early phases of training, final selection of diving teams had not been made. As team member replacements were made to the original trainee team, these new members required indoctrination and accelerated training to become checked out on the equipment. Detailed findings of the human factors studies are included as Appendix A.

Safety cannot be too highly stressed; this is especially true in diver operations. Therefore, instruction in the safe handling of the equipments selected for the Salvage Projects and safety procedures to be followed were primary considerations. Safety precautions have been discussed previously in this report.

Surface Training Results

Hunley-Wischhoefer Remote Recovery System. This system, completed and tested by the cognizant developing activity Naval Underwater Warfare Center (NUWC) prior to assignment to the Salvage Projects, is designed to assist in accomplishing several tasks related to salvage operations. Essentially, it can serve as a diver's load lift assist device, a marker buoy, or as a deployment vehicle for a messenger or guideline. The present configuration of the system permits a diver to attach it to an in-water load of up to 250 pounds, neutralize the weight by discharging ballast shot from the system, and then move the load about on the sea floor.

Surface training consisted of acquainting divers with the purposes for and capabilities of the recovery system as designed. Further training included familiarization with the functions of the system's component parts and step-by-step operating procedures. Divers participated in assembly and disassembly procedures. Safety precautions were stressed.

Collapsible Salvage Pontoon With 8.4-Ton Lift Capability. These pontoons are relatively uncomplicated. Diver efforts during operations utilizing these units will consist, principally, of manipulating attendant rigging (Figure 35), coupling and uncoupling inflation air hoses, and observation to ensure proper and complete inflation and deflation. Observations should also reveal potentially dangerous situations, fouling of rigging, and proper or improper functioning of pressure relief valves.

The 8.4-ton pontoon is designed for use as a component of a modular 25-ton lift system. Design considerations included coupling as many as three of the units end-to-end to provide a 25-ton lift force to be applied through an explosively attached padeye, also rated at 25 tons.

Surface training consisted of visual familiarization with the pontoon and its construction (materials and parts). Divers were also instructed in the proper care and maintenance of the pontoon carcass, proper torque of assembly bolts, corrosion control, and proper settings and operation of pressure relief valves. (Corrosion problems discovered during the training period resulted in replacement of all relief valve stud fasteners with studs of compatible materials.) Diver safety procedures were stressed.

Two-Ton Lift Capability Collapsible Salvage Pontoon. This pontoon, designed for assisting divers in making heavy lifts during movement of materials and equipment in the underwater environment, was originally equipped with a spring-loaded, liquid hydrazine fuel supply, to be passed over a catalyst bed for converting the liquid fuel to gaseous hydrogen, ammonia, and nitrogen. By varying the length of the catalyst bed, the exhaust temperature of the gasses can be regulated.

Surface training dealt with familiarization with safe handling procedures for the hydrazine fuel, the various components and functions of the hardware, and proposed operating procedures including those related to diver safety. Following initial shallow-water training, the spring-loaded system (Figure 36) was replaced with a resilient bag fuel supply device (Figure 8), and additional surface training was undertaken to acquaint the diver team with this equipment and with the purpose and operation of a gas relief valve incorporated into the top portion of the buoyancy bag. Divers were trained in preparing the system for use.

Variable Buoyancy Hydrazine-Fueled Device With 200-Pound Lift Capability. This device utilizes a liquid-to-gas conversion system almost identical, except for size, to the spring-loaded unit originally incorporated in the two-ton lift system. Instruction ashore included purposes and limitations of the device, servicing, assembly, and steps in operation. The initial configuration did not include a wide range variable buoyancy control, but served only as a light-object salvage or constant-lift assist device. Training with this configuration (Figure 11) was conducted also in the seawater tank (Figure 31).

Twenty-Five-Ton Lift Capability Padeye. Since this padeye incorporates ordnance materials, classroom instruction and training of divers included background information on salvage requirements, design parameters, research and development phase tests, and results and illustrations of the padeye in use. Second-stage training was conducted in a laboratory situation with manufacturer's representatives participating. This portion of the training utilized the hardware. Divers were drilled in the proper steps in assembly and disassembly including the loading of the projectiles in the sealed barrel (Figure 12). All safety precautions were particularly stressed.

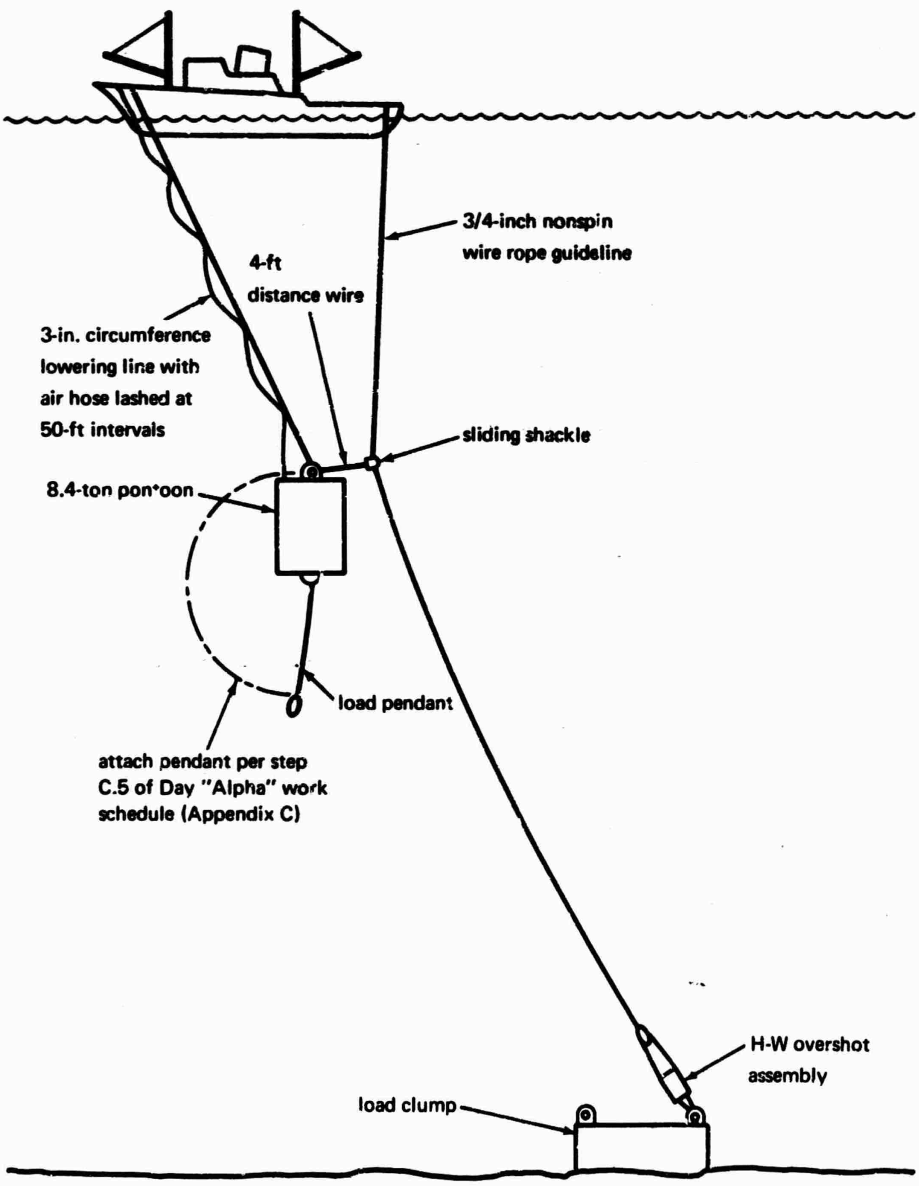


Figure 35. Rigging schematic for 8.4-ton pontoon.

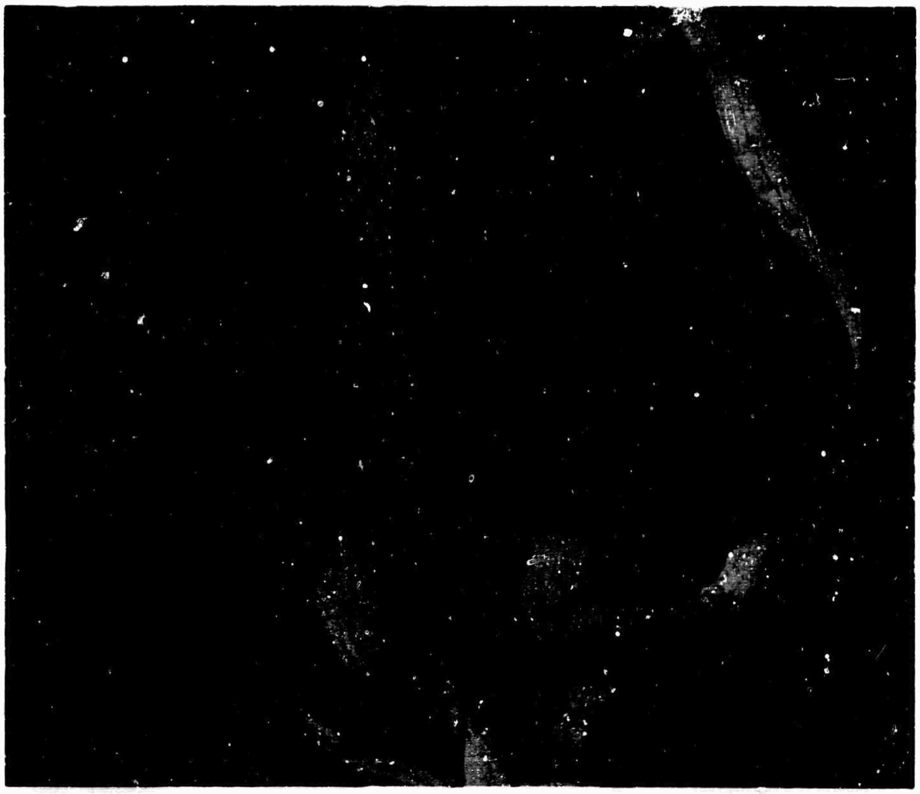


Figure 36. Two-ton salvage pontoon with spring-loaded fuel supply and gas generator.

The projectiles are preloaded in air, in sealed barrels, to assure a more uniform and increased penetration for a specific power charge when fired into the intended substratum, than would occur if the barrels were not sealed. Since the barrels, therefore, contain air at one atmosphere, a minimum recoil action results from firing the projectile as opposed to that which would occur if a slug of water preceded the projectile down the barrel. Water in the barrels at ambient pressure would also reduce the intended pressure differential resulting from the exploding power charge.

Chemical Overlay System. Project managers (NCEL) for this system first conducted classroom diver training at which time the background requirements were discussed and the developmental steps outlined. A scale model demonstration was performed followed by familiarization with the equipments and operational procedures of the full-scale system proposed. Because the chemical mixture contains water soluble materials the necessity for avoiding contamination of diver equipment and habitat environment was stressed. Such contamination can be avoided by using discretion on orienting the exercise in proper relation to habitat and direction of underwater currents.

Chemical Lights. The manufacturer's representative described the chemical function of the solutions from which the light was produced and the principles of the various design types. The method of activation was demonstrated, and units were activated in a dark room. Safety precautions were stressed.

Electric Underwater Power Tool. Personnel from Battelle Memorial Institute, Columbus, Ohio, conducted classroom instruction at NCEL on the tool development including the seawater–flooded motor design, switching circuits, impacting device, drive shaft design and speeds and their uses, tool accessories, and design capabilities and envelope design. Detailed instruction was also given on the design, operation, and capability of an electrical safety circuit device required for use with the tool system.

Instruction was then moved to a seawater tank (Figure 37) where use of the tool was demonstrated. Tool maintenance requirements were also discussed. The tool used in this phase was a preprototype model, with a 1/4-horsepower rating, which proved to be useful, when operating. Difficulties occurred with the switches, however. These electrical insulation failures served to demonstrate the reliability of the safety circuit.

Explosively Actuated Cable Cutter. Divers were provided with written materials describing the cable cutters, their design, purposes, operational procedures, and the safety precautions to be observed. Since the cutters are of the "throw away" type and their availability was limited, demonstrations were not possible, however, a previously activated unit was provided for familiarization with parts and firing procedures. The cable to be cut is shown in the upper left corner of Figure 29.

Explosively Actuated Stud Driver. Classroom instruction by NOL considered the purposes, design, safety features, and operational procedures of the stud driver. A film of the device in use was shown. The various types of projectiles and their uses were discussed. Laboratory instruction included familiarization with the hardware and component parts, projectile loading procedures, safe handling practices, actual firing training (Figure 38) both in air and in a seawater tank, and instruction on as well as demonstration of maintenance procedures. Safe handling procedures were emphasized. During this training, it was discovered that fabrication stackup tolerances were such that some stud drivers would not fire when certain projectiles were used. The stud drivers were returned to the manufacturer for corrective action. Figure 39 illustrates the results of use of this tool for attaching patch plates to a ruptured ship hull.

Figure 37. Divers with electric-powered tool at the seawater tank.

Air-Driven Saw. Divers were provided with a commercially available off-the-shelf saw (Figure 25) and shown the vital parts and method of changing blades and providing lubrication. The principle of operation, proposed test operating procedures, and safety procedures were discussed.

Hand Tools. Aquanauts were shown the various off-the-shelf tools (Figures 26 and 27) and test objectives and procedures were explained, with emphasis on the aspects of the human factors study. Divers performed the prescribed test in the seawater tank for human factors baseline studies.

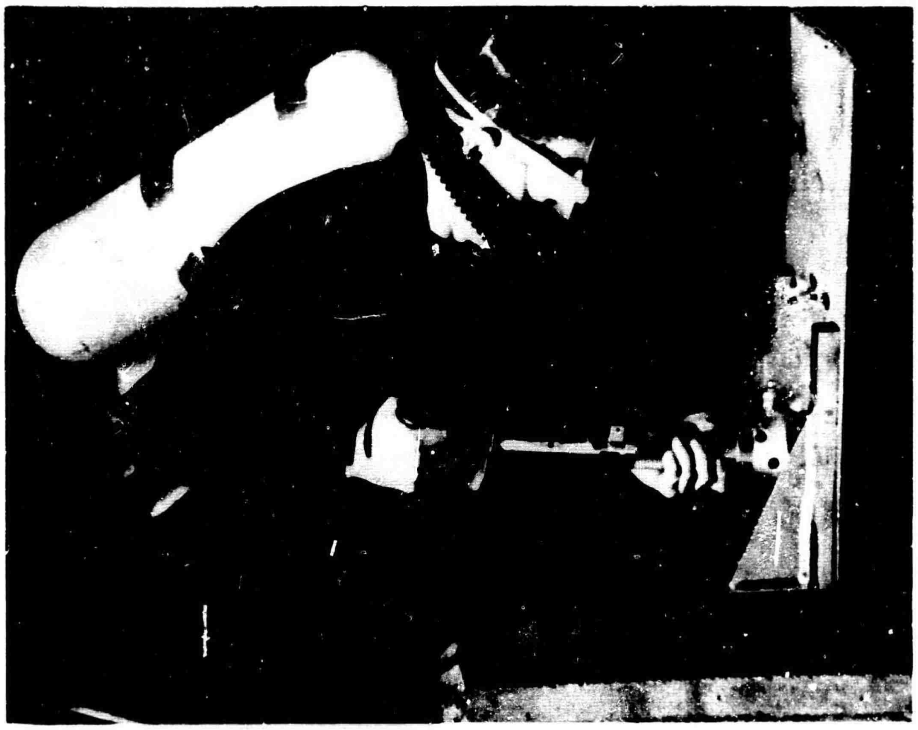


Figure 38. Diver operating explosively actuated stud driver.

Tool Test Stand. The divers were shown the test stand (Figure 28) and its various features were pointed out. The proper method of orienting the stand for use was demonstrated.

Human Factors Studies. Project personnel (NMC), assigned to conduct this portion of the test program, described their methods and purposes and discussed the procedure to be followed in debriefing the divers following each operational sequence.

Shallow-Water Training Results

Shallow-water diver training closely followed the protocol of proposed events for the Salvage Projects for SEALAB III in order to familiarize the diving team with the steps of those procedures. The training was conducted at two sites: in 25 to 30 feet of water off a pier at Point Mugu, California, and from the USNS ***GEAR*** anchored in 50 to 60 feet of water at Anacapa Island off the coast of California. The Anacapa Island site was chosen because of the advantages of the clear water found there. Advantages include the ability to see diving training with coverage by still photography and closed-circuit TV.

Figure 39. Diver showing stud penetration of 1-inch mild steel.

During early portions of this training phase, project engineers performed most of the topside preparation operations. Later, the ship's salvage crew performed many operations. This was in line with normal ship force functions.

Hunley-Wischhoefer Remote Recovery System. The first shallow-water training exercises with this system were conducted off the pier at Point Mugu. It was found that at this shallow depth (25 to 30 feet) the subsurface effects of wave action made it difficult for two divers to control the device when neutral buoyancy had been achieved. The relatively large, vertical, cross-sectional area also added to the problem due to lateral currents.

Later training in the 50 to 60-foot deep water at Anacapa Island revealed a potential danger to surface equipment and personnel. Successive tests demonstrated that the device did not rise vertically but followed an unpredictable path. Furthermore, the rate of ascent and mass of the device were sufficient to cause casualties, if a collision should occur with divers or equipment on the surface (Figure 40).

Figure 40. Hunley-Wischhoefer device breaking surface at an angle.

Recommendations were made to modify the system for purposes of these tests and for any subsequent exercise where support equipment or personnel are likely to be relatively immobilized on the surface in the near vicinity of or directly above the device as it is released. These recommendations called for a means to increase drag forces to slow the rate of ascent, and for a reduction in the maximum positive buoyancy attainable upon release of ballast shot and the male spear. This was accomplished by providing a removable dragskirt and sixteen, 13-pound lead weights which can be attached to the dragskirt to achieve a range of positive buoyancy.

Generally, the divers found the system relatively easy to manage at the 50 to 60-foot water depth. Additional recommendations were made for including a positive locking device to ensure that the buoy did not separate from the conical housing and an enlargement of the gate through which the ballast shot was bled to achieve neutral buoyancy.

Voiced criticism of the system, other than the hazards cited above, were:

1. The possible loss of the male spear release handles and/or safety locking pins.
2. The rather large expense of nonrecoverable lead ballast shot with each use of the system.
3. The comparatively large size and weight of the system, requiring considerable stowage space and presenting handling problems that necessitate topside use of mechanical hoisting and handling equipment.
4. The likelihood of the lead shot accumulating on or in the object suspended below as shot is released to acquire neutral or positive buoyancy.
5. Required use of comparatively expensive drums of specially coiled messenger line on a throw away basis after one use.
6. The large size would be intolerable where conditions of heavy surge or strong currents existed.

Collapsible Salvage Pontoon With 8.4-Ton Lift Capability. All in-water training with this pontoon was conducted at the Anacapa Island site because of the logistic support requirements and the water depth required due to the overall in-water height of the rigging system. The size and weight of the pontoon require mandatory use of cranes or booms for handling purposes topside and for lowering the pontoon and associated equipments to the ocean bottom training site.

Diver training with the 8.4-ton pontoon included the handling of the Hunley-Wischhoefer female overshot device. Diver duties in one instance required, as the first event, shackling a load pendant wire attached to the pontoon, to the bridle of the female overshot which was previously mated with the male spear. In the second event, the pontoon with the female overshot shackled in place was lowered down a guideline (messenger line terminating in the male spear) to the object to be salvaged. In this case, the diver acted as an observer to inspect for proper mating of the male-female devices (Figure 41). All air hose connections were made on shipboard.

The training sequence did not reveal any problem areas for the second event. However, initial efforts revealed that methods of rigging the load pendant for the first event would require modification. It was found to be virtually impossible for two men to handle the in-water weight and bulk of the pontoon; especially after it had come to rest on the sea floor. If the resting point was a greater distance from the salvage lift attachment point than the length of the load pendant, the divers could not complete the rigging. Further, if the load pendant was covered by the pontoon as it settled on the bottom, the divers could not wrestle it free. An effective solution was reached by providing a pendant of sufficient and reasonable length to ensure that it would reach the attachment point and lashing its free end to the padeye at the top of the pontoon (Figure 35). After freeing this end, the divers were able to wrestle the pendant free when covered by the pontoon. Divers are not permitted to move in close to handle the rigging while topside is manipulating the device and, therefore, cannot arrange the pendant such that it will rest free of the pontoon.

Figure 41. Diver inspecting string of three 8.4-ton pontoons.

For the shallow-water training, a portable air compressor was installed aboard the salvage ship to provide pontoon inflation air. Compressors of the construction industry type are adequate to provide required volume and pressure at these depths. However, when identical events are planned for deep water, these compressors will not provide the pressure or the volume of air at an acceptable rate. For deep water, large-capacity, high-pressure air storage must be provided aboard the salvage vessel. This air would be passed to the pontoons through pressure reducing regulators. Because of pressures involved at the deep water salvage site, all hose connections would be made on the surface.

Two-Ton Lift Capability Collapsible Salvage Pontoon. Initial shallow-water training was conducted utilizing the spring-loaded hydrazine fuel supply for the pontoon (Figure 36). The system operated successfully and management by the divers proved to be fairly easy. There were recommendations for changes, however. Access to the fuel control valve was through a zipper opening in the lower underside of the bag. As the bag filled with gas, the tendency was for the zipper opening to be stretched taut, thus essentially closing it. This then made it difficult for the diver to reach the valve to control the gas production. Also, it was difficult to deflate the bag since this had been conceived as one purpose for the zipper.

Following these first exercises, a vent valve operated by a lanyard was provided at the top of the bag. Because it was realized that, for deep depths, a large volume of liquid fuel would be required to fill the bag with the higher pressure gas, a new fuel supply system was designed. A spring-loaded, steel bodied system of adequate size would have been prohibitively heavy. The new design utilized a resilient bag, fuel storage vessel (Figure 8). The design for this system provided easy access to the fuel control valve.

Because the deflated 2-ton pontoon with fuel system was rather bulky and somewhat heavy, divers recommended using the smaller (200-pound capability) lift device to move the larger unit about. In practice, this proved to be a quite satisfactory method.

Variable Buoyancy Hydrazine-Fueled Device With 200-Pound Lift Capability. Early shallow-water training was conducted off the pier at Point Mugu. The original configuration was utilized. Divers recommended certain modifications, but were generally enthusiastic with the concept. The access hole for operating the fuel control valve was later enlarged to accommodate a gloved hand. Rigid buoyancy material was added inside the top of the shell to keep the device vertically oriented and to make the unit almost neutrally buoyant prior to filling with gas. A self-sealing zipper with a vent hole in the slide was installed (Figure 9). The slide is set for a predetermined buoyant lift force. This provides a means for ensuring a constant lift as the diver neutralizes the load on the sea floor and moves upward in the water. This was not possible with the original design due to expansion of the gas. As the diver descends again, he may "crack" the fuel valve to maintain constant gas volume.

For shallow depths, the liquid-fueled gas generating device can be replaced with a high-pressure gas cylinder or an air line from the support vessel. Small units of this design could be provided with gas from the diver's breathing gas supply.

The device proved to be a very valuable piece of diver equipment and was used to transport many of the other Salvage Projects equipments about the ocean floor training site. It could easily be adapted to accomplish the functions of the Hunley-Wischhoefer system and with many improvements over the present design of that system.

Twenty-Five-Ton Lift Capability Padeye. The padeyes are available in only very limited numbers. A total of three had been provided for the Salvage Projects for SEALAB III. Since the padeye cannot be easily removed when it has been attached to a plate, training was limited to assembling, handling, placement, and simulated firing tests conducted in conjunction with other salvage device development programs (Figures 42 and 43).

Chemical Overlay System. The equipment associated with this system is mounted on the tool test stand (Figure 44) and, therefore, training was conducted at the Anacapa site. The training exercises were also used to develop techniques in diver use of the equipment. As training progressed, various modifications of the equipment were made in accordance with diver recommendations based on development of operating techniques and upon equipment operation. Chemical composition of the plastic material used was also varied as a means of improving the results (Figure 45).

Following the shallow-water training, the equipment was completely redesigned (Figures 15 and 16) to provide a miniature model for use in the Salvage Projects for SEALAB III. Reasons for this change were: (1) to reduce the possibility of accidentally contaminating the habitat by inadvertently carrying inside some of the chemicals on diver equipment and (2) to protect the plot of overlay from damage by divers engaged in other activities. By laying the test plot in a tray on the tool test stand, it could also be returned to the surface with the test stand for observation and evaluation.

Chemical Lights. Diver shallow-water training with these devices was necessarily carried out in darkness in order to properly evaluate their effectiveness. The training was therefore conducted after dark and in the harbor at Port Hueneme, California. Although the harbor water was not clear as it would have been at the Anacapa site, it provided a realistic environment to evaluate the utility of the lights. Furthermore, various vessels were available on wh ch simulated hull inspections could be carried out and comparative dimensions of illuminated areas could be determined. Adequacy of lighting for carrying out repair work also could be judged. Light output for a 100 ml unit approximates 5 candlepower and may last 12 hours or more. It is concluded that there are many practical uses for these lights.

Figure 42. Diver installing firing pin on 25-ton padeye barrel.

Electric Underwater Power Tool. The 1/4-horsepower rated preprototype model of this tool development was used in early shallow-water diver training (Figure 46). Demonstrations by tool development personnel (Battelle) of the effectiveness of the electrical safety circuit breaker encouraged diver acceptance of the power tool. While using this tool in the seawater environment, the diver quickly overcame inhibitions acquired from years of electrical safety training. Tool project development personnel were on hand to effect repairs frequently required for this early-development-stage tool model.

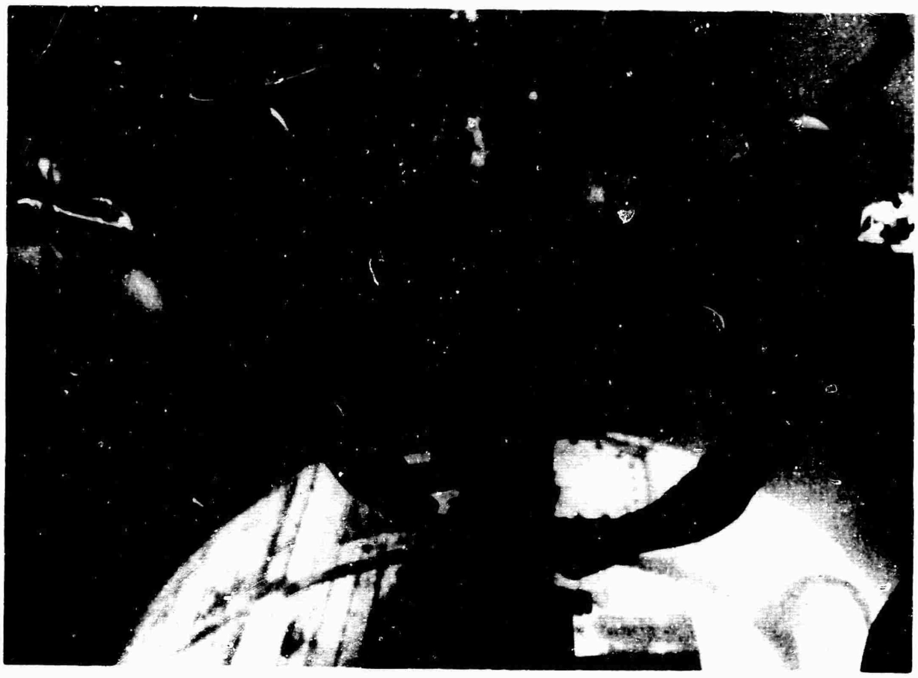


Figure 43. Divers firing a stud on the 25-ton lift capability padeye.

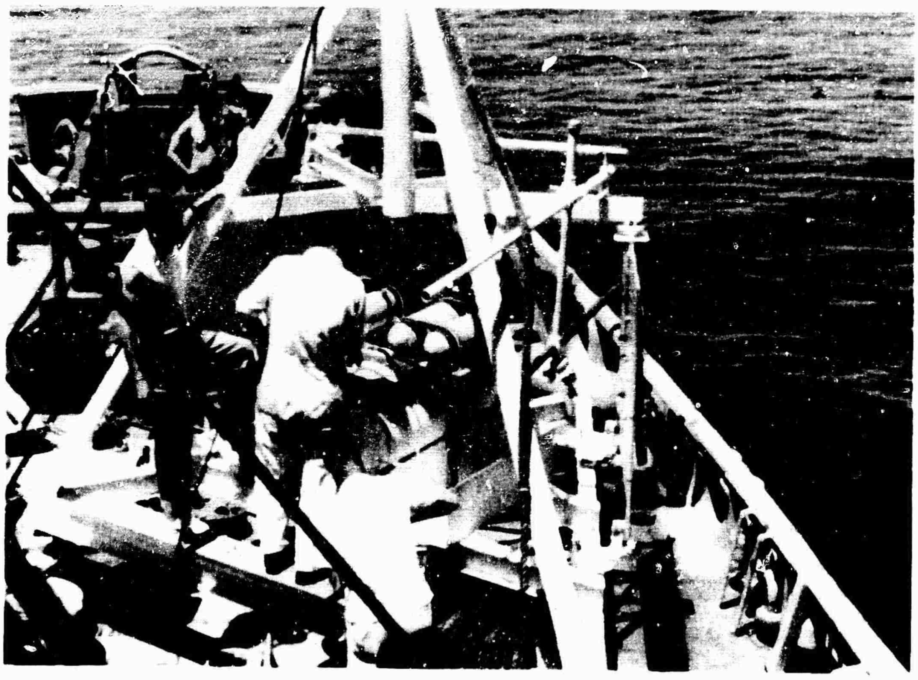


Figure 44. Personnel servicing the prototype chemical overlay equipment.

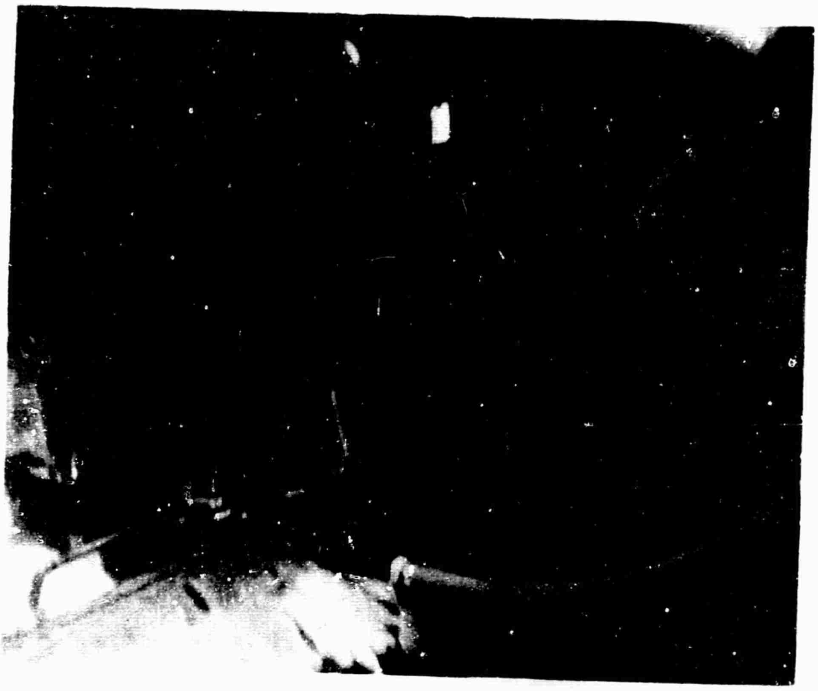


Figure 45. Diver starting to place a ribbon of chemical overlay.

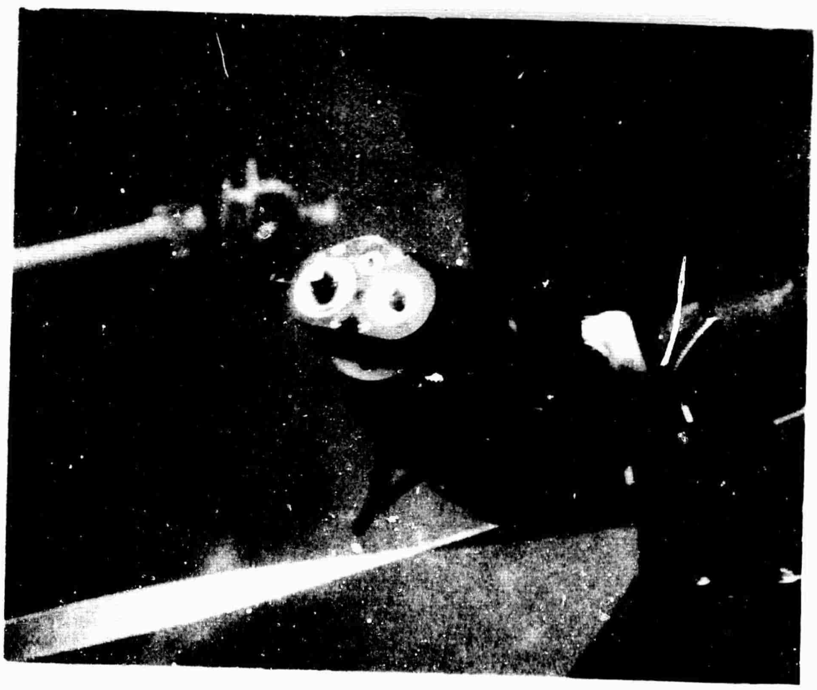


Figure 46. Diver leaning into tethering strap, preparing to use the electric underwater tool.

Following these early tests, two units of the second generation model of the tool were completed. These tools had been expected for the early tests, but had been delayed. The nominal rating for these tools is 5/8 horsepower. Divers experienced some difficulties with the new power tools also. Some of the complaints registered were:

1. Not powerful enough
2. Bits jammed often
3. Attaching the impacting device was difficult
4. Bits wobbled in the toolholder adapter
5. Overall length of the assembly equipment made it difficult to use (Figure 18)

The second generation model of the tool also suffered electrical failures in the switch assemblies due to seawater intrusion. The tools were returned to the developer for corrective action.

Explosively Actuated Cable Cutter. The cable cutters were not exercised in shallow-water training because of the short supply of the devices.

Explosively Actuated Stud Driver. During shallow-water training at the Anacapa site, the divers approximately duplicated the procedures called out in the scenario to be used in the Salvage Projects for SEALAB III. In the interest of conserving materials and equipment, studs rated for both 1-inch and 1/2-inch plate were fired into a single test setup. Results are shown on the square test plate on the left side in Figure 29.

With the stud driver, as was also true of the electric underwater power tool, divers experienced inability to judge accurately when the equipment was oriented 90 degrees to the work surface. Since one of the safety features designed into the stud driver prevents firing when disoriented more than 8 degrees, some misfires were reported that may, in reality, have been diver error. This tendency to misalign the tools was noted by both diver observers and personnel monitoring the closed-circuit TV.

Air-Driven Saw. Exercises utilizing the saw (Figure 47) came late in the training phases. A belated decision had been made to include the saw in the Salvage Projects. Divers experienced little difficulty in using the saw; difficulties reported concerned the changing of blades. A special wrench was designed to aid this effort.

Figure 47. Diver exercising the air-driven hacksaw on 1/2-inch plate.

Hand Tools. Divers experienced no difficulty in using the hand tools. The primary purpose was to provide data for the human factors studies. An example of a diver making use of the tethering strap while working is shown in Figure 48.

Tool Test Stand. Early training revealed certain desirable modifications to increase the effectiveness and utility of the test stand. The TV camera and light booms were completely redesigned. The new design included a boom position-locking device and two extension members for each boom to permit wider coverage by the TV camera and light mounts. Double ball-joint swivels were provided to permit more flexibility in the TV camera mounts. Additional tethering points were added to the test bed backing plates and adjustable tethering straps were provided. In an actual salvage operation, movable magnets could serve as versatile tethering points.

Training with the modified test stand (Figure 49) revealed no difficulties. Divers were able to orient the backing plates and ready the camera and light booms for use in 14.5 minutes.

Figure 48. Diver utilizing tethering strap while exercising hand tools.

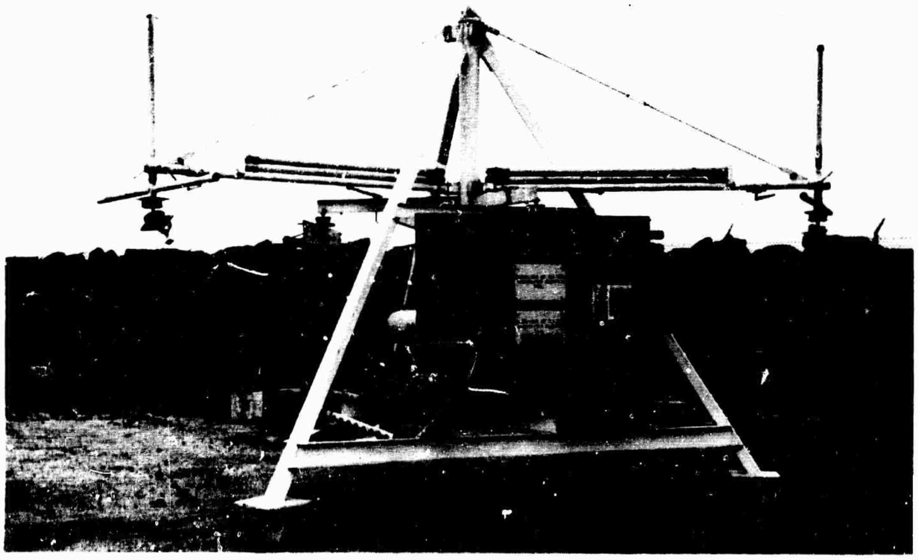


Figure 49. Modified tool test stand.

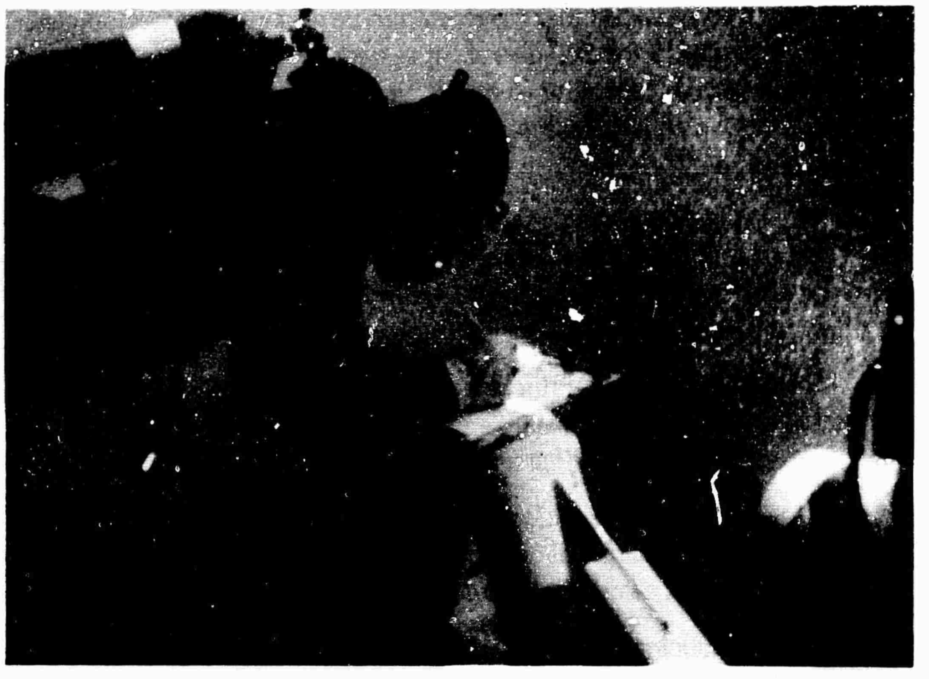


Figure 50. Diver recording human factors data.

Human Factors Studies. Figure 50 shows a monitor collecting data. Appendix A details these studies. Typical mean times required to complete major subtasks are listed in Tables 2 through 5. The total times required represent approximate bottom time per exercise and are greater than the combined subtask times since the time required for communications, adjustments, etc, are not listed.

FUTURE PLANS AND RECOMMENDATIONS

It is not unlikely that modifications to the equipments described in this report will be required to reflect the availability of new materials and technology. Advisable changes will be brought to the attention of persons concerned.

Equipments held at the NCEL staging point will be maintained in a ready state in order to remain sensitive to a "quick response" or emergency call. Thi will ensure their availability for use with such operations as TEKTITE and the Supervisor of Salvage MARK I diving system. Such usage will provide additional valuable diver training and opportunity for further critical review of developing techniques and criteria.

It is recommended that consideration be given to the development of a device, similar to the 200-pound lift system, which would incorporate the remote recovery capability of the Hunley-Wischhoefer system but with improvements which are feasible. Some of the improvements that could be incorporated are:

1. The messenger line which is now obtained specially wound in individual containers for one-time use only could be placed on a reel and rewound after each use. The specially wound line is relatively expensive in addition to being a one-time use item.

2. Use of a gas generator or air flask system together with an adjustable buoyancy device would eliminate the need for ballast shot which is also expensive and a one-time use item.

3. Use of a collapsible device would overcome the disadvantage of the heavy weight and large sail area divers experience while maneuvering and handling the present remote recovery system.

4. By reducing the size, weight, and supplemental material requirement of the system, the necessity for shipboard handling equipment and storage space would be reduced.

Table 2. Electric Underwater Power Tool

Task	Elapsed Time (min and sec)
Attach tool box	01:01
Tether in	01:37
Punch six holes	00:44
Drill two 27/64-in. holes	03:38
Drill two 5/8-in. holes	04:03
Saw one 3/4-in. hole	01:07
Saw one 1-1/2-in. hole	01:29
Mount impactor	00:57
Tap two 1/2-13 holes	02:36
Torque two bolts	00:41
Attach pipe flange (punch, drill, tap, locate, and torque)	14:20
TOTAL TIME REQUIRED	45:00

Table 3. Hunley-Wischhoefer Remote Recovery System

Task	Elapsed Time (min and sec)
Drop shot	01:56
Move system 20 feet	00:40
Shackle to load	00:47
Pull pins and handles	00:35
TOTAL TIME REQUIRED	13:00

Table 4. Twenty-Five-Ton Lift Capability Padeye

Task	Elapsed Time (min and sec)
Attach lift device	01:00
Move load 20 feet	02:17
Pull safety pins	00:27
Simulate firing four barrels	01:50
TOTAL TIME REQUIRED	12:00

Table 5. Chemical Overlay System

Task	Elapsed Time (min and sec)
Uncoil hose	01:10
Open control valves	00:47
Move off 20 feet with applicator	01:02
Lay 10-foot strip of overlay	03:01
Secure valves	00:32
Secure hose and applicator	03:00
TOTAL TIME REQUIRED	14:30

Appendix A

HUMAN FACTORS FINDINGS

by

*Frederick B. Barrett and **Michael Wolfe

INTRODUCTION

The Human Factors Engineering Branch, Naval Missile Center, Point Mugu, California, was assigned the task of collecting diver performance data during the salvage trials. The trials were conducted under the supervision of the U.S. Navy Supervisor of Salvage, the Deep Submergence Systems Project Office, and the Naval Civil Engineering Laboratory. Dr. G. Weltman and Messrs. B. Elliot, T. Crooks, L. Christianson, and R. Miles, all of UCLA, John Quirk of NCEL, and Dale Phillips of NMC, assisted the authors as diver observers for the underwater trials.

The salvage trials were conducted in the open ocean near Point Mugu in January 1968, at Anacapa Island from 21 May through 29 May, and again at Anacapa Island from 13 August through 28 August 1968. The trials at Anacapa were conducted at an approximate depth of 50 feet. The USNS ***GEAR***, a salvage ship, was used for logistics and operational support. The ship was placed in a two-point moor and the salvage systems, as required, were lowered over the side by the ship's cargo boom.

Among the goals of the trials were the assessment of diver performance, the development of improved work procedures, improved equipment design, and the collection of baseline data for comparison with forthcoming trials at much greater depth.

The following U.S. Navy and civilian personnel participated in the salvage trials as working divers:

Lt. M. C. Eggar	R. Garrahan, WO
F. Buski, SF1	S. E. Huss, DC1
W. Ramsey, Ph1	T. W. Reedy, HM1
F. S. Reando, MR1	T. Robinson (civilian oceanographer)

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These personnel are qualified first-class divers and have been in training for the 600-foot-depth habitat trials. They were most cooperative and knowledgeable and responded with many constructive suggestions for improving the salvage equipment and methods. The recommendations which follow were based largely on their debriefing inputs.

The methods and equipment used for collection of diver performance data are described in Appendix B.

A complete list of the diver's responses to the debriefing questionnaires has been forwarded to ONR, DSSPTO, and NCEL under the titles of "Diver Debriefing, SEALAB III Salvage Trials," May 1968; and "Human Engineering Report, SEALAB III Shallow Water Construction Trials, Anacapa Island," May and August 1968, - Code 5342, Naval Missile Center, Point Mugu, Calif. This review includes only those recommendations or comments of the divers considered to be of particular importance from the human factors and/or systems engineering standpoints. In some instances, the recommendations are based on the human factors observers observations of the underwater trials and surface operations. The latter recommendations may, therefore, differ from or not be included in the diver debriefing data.

DISCUSSION AND RECOMMENDATIONS

General Recommendations

There was inadequate time to thoroughly plan some of the operations and to design and build the most effective equipment before the trials were conducted. This was not always the case. Some of the inadequacies discovered could probably have been corrected or avoided prior to underwater testing. It is recommended that discussions be held with experienced salvage divers and engineering and human factors personnel during the next salvage equipment design phase if possible. For many operations, it may be possible for such personnel to "walk through" the operations using prototype equipment and point out features of equipment either difficult, unsafe, or inefficient to work with under water. Utilizing this technique, it would be possible for personnel to recommend operational changes possibly resulting in more effectiveness and less hazard.

Salvage system development engineers performed most of the early topside preparations. Since this phase of the work is almost as crucial as the underwater work for a successful salvage operation, it is recommended that salvage ship personnel perform such operations. Such personnel should be representative of the probable users of the equipment in terms of experience and training. It would then be possible to obtain their evaluations of the surface operations and the extent to which they would be practical in salvage work. A series of steps may be simple for development engineers and technicians, but be confusing to others with differing backgrounds.

An object with a volume of a single cubic foot is extremely difficult to swim with in a strong current. Large objects such as the Hunley-Wischhoefer system would probably drag two divers along in a strong current. Furthermore, requiring divers to work at near maximum effort is dangerous at great depth; when diving, life support equipment can be overbreathed; there is also possible danger from CO_2 buildup.

It is possible and likely that salvage equipment may be stored for long periods of time. Moreover, in an emergency, the equipment may be used by personnel not thoroughly familiar with its operation. It is therefore recommended that the equipment be stored in containers where all required parts, special tools, and complete instructions for use may be protected from loss and environmental damage. The operating procedures should be made as simple and foolproof as possible, the instructions should be clear and concise, and the need for special tools and exotic supplies held to an absolute minimum.

If special fixtures are required, they should be designed to function under adverse environmental conditions, including high sea states. They should be stored with the related salvage equipment.

In order to more thoroughly evaluate the salvage equipment concerned in this review, it would be advisable to repeat the tests under more severe conditions of visibility, water temperature, depth, turbidity, surge, etc.

The following documents are recently published specifications and standards which define human engineering requirements and criteria for military systems, equipment, and facilities. Recently, promulgated amendments to these documents direct their mandatory use by all departments and agencies of the Department of Defense.

1. Military Specification MIL-H-46855, "Human Engineering Requirements for Military Systems, Equipment and Facilities," and Amendment 1 thereto.

2. Military Standard 1472, "Human Engineering Design Criteria for Military Systems, Equipment and Facilities," and Notice 1 thereto.

Safety

The electric underwater power tool motor has an automatic safety circuit to decrease the hazards of underwater shock, however, the divers will also be required to work with or near underwater lights used for photography and general lighting. These lights are not provided with safety circuits.

The understanding obtained from authoritative sources was that the divers had received thorough instruction in the emergency modes for using the MK VIII breathing apparatus. No tests of emergency procedures involving any of the diving equipment during the salvage trials conducted at Anacapa Island were observed. Emergency use modes must be practiced to the point where the required diver response is almost reflexive, thereby increasing the chances of proper execution under adverse conditions.

It is recommended that the feasibility and practicality of the following proposal be considered. Require each diver to use the MK VIII equipment in each of the emergency modes, a few feet from the habitat, while under close supervision, prior to permitting any distant excursions. Plan and rehearse all related topside emergency procedures, separately and jointly.

The psychological problems associated with using the equipment at 600 feet under emergency conditions may be markedly different from those at shallow depths. It is believed that the proposed training would reduce the probability of inappropriate or panic responses.

Electric Underwater Power Tool

The electrical tool and impactor were redesigned following the May trials. The nominal power was increased to 5/8 horsepower. The five divers who commented, stated that the torque produced by the tool did not compare favorably with that produced by a 5/8-horsepower drill motor designed for conventional shop use; the observers agree. The tool bits jammed often when drilling and tapping 1/4-inch-thick mild steel. The majority of the divers consider the tool adequate for salvage work and were much impressed with its safety features. The design engineers were very responsive to suggestions made following the May trials. This was both noticed and appreciated by the divers.

The impactor worked very well and is the type of relatively torque-free tool that is particularly well adapted to underwater use. However, the impactor was difficult to align with the tool drive shaft and its locking lever was rather small for handling while wearing gloves. Considerable wobble was evident, initially, when tool bits were being used. This tendency was reduced by shortening the drill bits. It is difficult to make the adapters and tool bits easily removable while holding close tolerances; some improvement is desirable.

The combination of drill motor, impactor, adapter, and tool bit creates an unusually long tool when compared with commercial shop equipment. Divers considered it too long for easy use.

Two of the divers found the reverse switch easy to activate accidentally, even though it was much improved following the May trials.

Comments on the tool box were very constructive. The holes in which the drill bits fit could be the same depth and all tool bits the same length. This would eliminate the present hunt and peck system for finding which drill belongs in which hole. The center punch should be painted a bright color because it is difficult to locate. The present hammer handle floats up unless put in a clip; a small amount of lead in the handle would eliminate this problem.

The tool box should be kept as small as possible to avoid excessive drag when used where currents may be strong. Accessibility of contained tool accessories must be considered, however. The box may be used in the dark or in turbid water and where currents or surge are present. The tool box should, therefore, be designed to prevent accidental loss of the contents. Adequate handles should be provided to aid underwater transport.

The tool box has been provided with magnets for securing it to the workpiece. Underwater structures of ferrous materials will often be heavily coated with antifouling or other paint and covered with varying amounts of marine growth. For this reason, magnets intended for underwater use should be several times as powerful as those required for clean metal. Furthermore, the surfaces may be curved, overlapped, or bent. The magnets should, therefore, be capable of swiveling to function effectively on such surfaces. If three magnets are provided, each would more readily come in contact with all but extremely curved or irregular surfaces, whereas, four or more would present more difficulty.

It was observed that it is difficult for most divers to align tool bits squarely with the workpiece. The buddy diver, observing the angle of the bit with the work surface, could correct this error for the working diver. Such assistance by the buddy diver should be routine.

It becomes exceedingly laborious to drill holes through steel plate using dull drills. Spare sharp drill bits of each required size should always be provided.

It is recommended that a second handle be provided that could be slipped over the tool and rotated into any position. The handle could serve as the fastener to hold its attachment ring in place. The divers differed considerably in their preferences for the position of such a handle, and in some cases it may not be desired. An adjustable and removable handle is, therefore, desirable. The need for a second handle will be much greater when the tool has been modified to deliver a full 5/8 horsepower. The torque imposed on an operator is quite severe when a drill of this size jams, particularly if held in one hand.

The electric underwater power tool is considered very safe to use. The safety circuit control unit may be subjected to severe environmental conditions and very rough handling during salvage operations. The unit should be designed and tested for such use, as should the mating electrical connectors and cables.

Chemical Overlay System

The applicator assembly was rebuilt aboard the USNS ***GEAR*** during the May trials. It proved easier to use, but some means of readily cleaning the applicator is also needed.

The applicator was modified after the May trials and the hose diameter reduced. Seven of the eight salvage divers stated that the new applicator did not result in a more effective application of the chemical overlay.

Bottom stabilization using the chemical overlay has possibilities when refinement of methods, equipment, and material have been accomplished. The present methods are rather difficult and time consuming both aboard ship and under water. The bottom overlay produced in the tests had bubbles, holes, and gaps and was too fragile for practical use.

Divers commented that, for salvage operations in a restricted area, it would probably be more practical to use a large canvas or heavy plastic sheeting . Small lead weights could be permanently attached at frequent intervals and the material folded in a manner that would make it fairly easy to unfold on the bottom. These materials would support work immediately and could be weighted to stay in place in moderate current or surge. When large areas must be covered, and when underwater work vehicles become available, it may become possible to utilize large rolls of the materials which could be unreeled on the bottom.

While using the tested equipment, the divers found it much easier to move about on the bottom with weighted anklets, with their swim fins removed.

Collapsible Salvage Pontoon With 8.4-Ton Lift Capability

It was found to be important that the pontoon be placed as close to the load clump as possible. If the pontoon is not properly placed, it must be moved and moving the pontoon is virtually impossible for two men. As a consequence, the size of the team would have to be significantly increased or a come-along or similar pulling device would have to be furnished. The latter appears to be the most practical approach and is highly recommended for this operation. A fair-lead was used to guide the pontoon down the quide cable. The divers viewed this with some apprehension, particularly if it were to be used in heavy seas.

The pontoon is quickly and easily inflated and no problems in this area were uncovered.

Hunley-Wischhoefer Remote Recovery System

The following suggestions were made subsequent to the May trials.

For some operations, it would probably be much simpler to attach a large lifting cable without using the messenger line and buoy. The buoy is large and would be difficult for divers to handle in surge or current. Buoyancy material could be added to the male prod such that it could be moved by divers without the use of a buoy. In shallow water, a diver could take the end of a messenger line down, leaving the reel aboard ship. He could attach the male prod to the load and in turn attach the messenger line to the male prod. (An improved method of attaching the messenger line to the male prod is required.) The female overshot could then be lowered down the messenger line as was done.

Loading and discharging the ballast shot was slow. To load, it was necessary to lay the fairing assembly on its side, remove a plug, and insert a funnel. Since the messenger buoy must be removed to resupply the line, it may be possible to load the shot directly into the ballast tank by adding a large trap door in the upper inner surface of the fairing cone (below the line spool). An alternate method would be to provide a funnel with a curved spout to permit faster loading with the assembly in an upright position.

The handles were difficult to remove, on occasion, and their safety pins could be easily lost.

Three long screwdrivers or similar devices were originally required to remove the male prod from the overshot. A simpler and faster method is advisable.

There is no control of the released buoy which rises very rapidly in the water. The buoy could strike a support craft or diver. The divers should stay on the bottom or come aboard before the buoy is released. Some means of buoy ascent control is advisable. Suggestions following the August trials were generally the same.

Tool Test Stand

The photo and salvage divers had many constructive suggestions for improving the original TV camera support assembly following the May trials. This equipment was modified and functioned very effectively during the August trials.

The stand was relatively easy to place on the bottom and adjust to provide correct test plate alignment.

Twenty-Five-Ton Lift Capability Padeye

The padeye was not difficult to move about or position with the aid of the variable buoyancy hydrazine lift system. Projectiles were not available for test firing, but simulated operation indicated a successful device.

Several of the salvage team divers suggested providing a firing lanyard for each barrel rather than a single lanyard. (Firing of two or more barrels simultaneously would require engineering and safety approval.)

Hydrazine-Fueled Variable Buoyancy System With 200-Pound Lift Capability

This item of equipment was redesigned following the May trials and thereafter functioned in a very satisfactory manner. Variable buoyancy could easily be obtained by setting the adjustable waterproof zipper to the indicated desired lift capability.

The hydrazine fuel valve could be easily reached and activated while wearing heavy gloves.

A large hydrazine fuel capacity is advisable for operations in which repeated use is anticipated or required.

The successful operation of this system is an excellent example of designer and test team cooperating to achieve a practical salvage tool.

Two-Ton Lift Capability Collapsible Salvage Pontoon

The pontoon was rather large and bulky and, therefore, somewhat difficult to move on the bottom. When deflated, it could be moved by using the variable buoyancy hydrazine generator to obtain a neutrally buoyant combined system.

It was necessary to reach the hydrazine fuel control valve through a zippered opening. This became difficult when the pontoon was inflated because tension on the fabric tended to hold the zipper opening closed.

Some divers found the vent control valve difficult and slightly hazardous to operate. It is recommended that the vent control valve be made readily accessible from either side of the pontoon so that a diver can work from either side of an inflated pontoon without having to be above or below the pontoon and load. Divers with umbilical cables have great difficulty moving rapidly and there is always the possibility of getting the umbilical tangled with the equipment.

Hand Tools

The purpose of this test was to obtain comparative measurements for divers using the tools at 50 feet and 600 feet. The divers found the hand tool test plate and toolholder effective for the tools being tested and appropriate for test stand type usage

Explosively Actuated Stud Driver

The stud drivers functioned well except for occasional misfires. This problem should be corrected.

Air-Driven Saw

The saw tested functioned quite well with a few exceptions. It was necessary to change blades using a small allen wrench stowed on the tool. This wrench could easily become lost and was difficult to handle, especially with heavy golves. The task of replacing blades would be difficult in dark or murky water.

The lube oil vial is quite small and is not adequate for prolonged use.

The saw cutting speed was relatively slow. Saw blades should be selected which are appropriate for the material to be cut, the stroke speed of the saw, the water environment, and the force which the divers may be expected to exert.

Diving Equipment

The Diving Unlimited open-circuit hot water suits were used without difficulty. The divers found them to be comfortable and very effective. It was suggested that better individual control of water temperature be provided to permit individual temperature selection when two or more divers are working at the same time.

O-rings on the MK VIII mixed gas breathing apparatus failed three times and resulted in one flooded CO_2 canister. Individual divers also had difficulty with faceplate fogging, clearing of ears, and obtaining a proper seal of the clamshell helmet mask against their face.

Umbilical hoses make it noticeably more difficult for the divers to swim in the water and slightly more difficult to walk on the bottom. There were a few instances of divers getting their umbilicals tangled in other cables or equipment. With experience, divers become more proficient in keeping their hoses clear. Less experienced divers will find it necessary to devote extra attention to this problem.

Conclusions

The DSSP salvage divers performed the assigned tasks with a minimum of difficulty. They were very cooperative and put a good deal of effort into evaluating the equipment and providing suggestions for design and operational improvements.

Only two task elements were or could become excessively difficult: (1) the 8.4-ton pontoon is practically impossible to move on the bottom without providing some device to gain mechanical advantage and (2) it was possible for the divers to swim with a large object such as the Hunley-Wischhoefer system only because there was very slight current. The divers would be carried along by a strong current or surge.

All other tasks were fairly simple and none required a great deal of reasoning or troubleshooting ability. It is recommended that similar additional tasks be provided in the future to more completely evaluate diver performance capabilities.

The methods used in monitoring diver performance and debriefing the divers proved satisfactory. Without the opportunity afforded by first-hand underwater observations, evaluation would be almost impossible and problems difficult to understand.

The salvage test equipments, in general, functioned satisfactorily considering the early stages of their development.

The USNS *GEAR* was highly cooperative as a support ship The salvage crew aboard was extremely helpful and functioned efficiently in execution of the surface support tasks.

The exercises were very helpful to the equipment design and to project engineers who actively participated in the surface preparation of the equipment and took the opportunity to discuss problem areas with the salvage divers.

Anacapa Island proved to be an excellent site for the shallow water trials. The underwater visibility was good, the temperature not excessively cold, and the cove fairly well protected from ocean waves.

The divers, generally, considered the team size and training adequate, but felt it could be improved by using the same diving gear—including heated suits and umbilicals—that would be used for saturation dives.

MEAN SALVAGE TASK TIMES

Mean times required to complete each major subtask were computed. The number of divers accomplishing each of the tasks varied from two to seven. Data sheets for each dive, listing the actual subtasks performed, elapsed times, divers and observers names, and the observers comments are included in the references cited in the appendix introduction.

The "Total Times" listed for the following salvage tasks are greater than the combined subtask times because the time required for other factors such as communicating, adjusting, etc, are not listed. The total time represents the approximate total elapsed bottom time required for the task.

Electric Underwater Power Tool

Subtask	Elapsed Time (min and sec)
Attach tool box	01:01
Tether in	01:37
Punch six holes	00:44
Drill two 27/64-in. holes	03:38
Drill two 5/8-in. holes	04:03
Saw one 3/4-in. hole	01:07
Saw one 1-1/2-in. hole	01:29
Mount impactor	00:57
Tap two 1/2-13 holes	02:36

Subtask	Elapsed Time (min and sec)
Torque two bolts	00:41
Attach pipe flange (punch, drill, tap, locate, and torque)	14:20
TOTAL TIME REQUIRED	45:00

Tool Test Stand

Subtask	Elapsed Time (min and sec)
Plumb test plates and install camera and light	14:30

Hunley-Wischhoefer Remote Recovery System

Subtask	Elapsed Time (min and sec)
Drop shot	01:56
Move system 20 feet	00:40
Shackle to load	00:47
Pull pins and handles	00:35
TOTAL TIME REQUIRED	13:00

Twenty-Five-Ton Lift Capability Padeye

Subtask	Elapsed Time (min and sec)
Attach lift device	01:00
Move load 20 feet	02:17
Pull safety pins	00:27
Simulate firing four barrels	01:50
TOTAL TIME REQUIRED	12:00

Chemical Overlay System

Subtask	Elapsed Time (min and sec)
Uncoil hose	01:10
Open control valves	00:47
Move off 20 feet with applicator	01:02
Lay 10-foot strip of overlay	03:01
Secure valves	00:32
Secure hose and applicator	03:00
TOTAL TIME REQUIRED	14:30

Collapsible Salvage Pontoon With 8.4-Ton Lift Capability

Subtask	Elapsed Time (min and sec)
Shackle to load	00:45
Unshackle from load	00:53
TOTAL TIME REQUIRED	07:45

Hydrazine-Fueled Variable Buoyancy System With 200-Pound Lift Capability

Subtask	Elapsed Time (min and sec)
Attach to load	01:07
Blow generator	01:20
Move load 30 feet	01:30
TOTAL TIME REQUIRED	15:00

Two-Ton Lift Capability Collapsible Salvage Pontoon

Subtask	Elapsed Time (min and sec)
Shackle to load	01:32
Inflate pontoon	[illegible] 37

Subtask	Elapsed Time (min and sec)
Vent pontoon	03:00
Unshackle	00:30
TOTAL TIME REQUIRED	14:00

Explosively Actuated Stud Driver

Subtask	Elapsed Time (min and sec)
Move guns and barrels to stand	02:00
Fire six studs (for 1/2-in. penetration)	05:30
Fire six studs (for 1-in. penetration)	02:50
Place and torque six nuts	03:32
TOTAL TIME REQUIRED	21:30

Hand Tools

Subtask	Elapsed Time (min and sec)
Attach plate and tools	02:54
Loosen and retighten pipe fittings	01:00
Loosen and retighten hydraulic fittings	00:23
Loosen and retighten six round head screws	00:30
Loosen and retighten six Phillips head screws	00:29
Loosen and retighten six allen head screws	00:20
Loosen and retighten six hex head screws	00:44
Loosen and retighten 3/4-in. bolt with crescent wrenches	00:21
Loosen and retighten 3/4-in. bolt with box end wrenches	00:15

Subtask	Elapsed Time (min and sec)
Loosen and retighten 3/4-in. bolt	00:19
with open end wrenches	00:19
Loosen and retighten 5/8-in. bolt with crescent wrenches	00:15
Loosen and retighten 5/8-in. bolt with box end wrenches	00:19
Loosen and retighten 5/8-in. bolt with open end wrenches	00:04
Loosen and retighten 1/2-in. bolt with crescent wrenches	00:11
Loosen and retighten 1/2-in. bolt with box end wrenches	00:09
Loosen and retighten 1/2-in. bolt with open end wrenches	00:06
Loosen and retighten 3/8-in. bolt with crescent wrenches	00:13
Loosen and retighten 3/8-in. bolt with box end wrenches	00:07
Loosen and retighten 3/8-in. bolt with open end wrenches	00:14
TOTAL TIME REQUIRED	21:00

Appendix B

AIDS USED IN HUMAN FACTORS EVALUATION OF DIVER PERFORMANCE AND TOOL AND EQUIPMENT FUNCTION

Several methods were used for collecting human factors data. The working divers were watched at all times by diver observers, supplemented by underwater television and photography where applicable. The divers completed questionnaires and answered detailed debriefing questions during interviews. The observers also witnessed topside preparation of the salvage equipment.

The diver observers used data recording boards and underwater timers. The steps or task elements, such as listed in Figure B-1, were prerecorded on white plastic sheets when the task was relatively routine. Task element completion tiimes were recorded and notations made of diver or equipment problems.

The tool test stand was provided with a television camera boom. Where the work area was stationary, as in the drill task, the camera was aimed at the work area and diver performance could be observed using the television monitor located topside. Video tapes of selected portions were made and retained for review and training purposes. Both surface preparations and the underwater trials were well documented through the use of still and motion-picture photography.

Following completion of each of the test trials, the divers filled in the Task Elements Ranking, Diving Factors, and Troubleshooting Check list forms (Figures B-1, B-2, and B-3). The forms were designed to obtain comparative information concerning the relative difficulties of the various task elements, the importance of diving factors such as visibility and diver strength, and to point up the reasons for difficulty in accomplishing the task elements, if any, together with the divers estimates of the relative difficulties or ease of accomplishment. The forms were processed by Dr. G. Weltman, Bioengineering Laboratory, UCLA, who will report on the results in a separate document.

A form similar to that for the hand tools (Figure B-4) has been prepared for each salvage task. The forms were designed to obtain data contrasting the relative difficulty of working at 50- and 600-foot depths and will be given to the divers following completion of the saturation dives.

Questionnaires were prepared for each of the salvage tasks, and human factors personnel tape-recorded the divers responses to the questions. Following are the questionnaires administered after the trials were conducted in August 1968, and the general instructions that were read to each test diver. (Diver responses are contained in Appendix A.)

TASK ELEMENTS RANKING

Task: ____________________ Team: ____________________

Date: ____________________ Diver: ____________________

Rank the following task elements according to their difficulty. Give the rank 1 to the most difficult element, the rank 2 to the next most difficult, etc.

Task Element	Rank
Sample elements for the 25-ton padeye task are listed below:	
Attach lift device	
Move load to test stand	
Pull safety pins	
Fire four barrels	

Figure B-1. Task elements ranking form.

DIVING FACTORS

Task: ______________________ Team: ______________________

Date: ______________________ Diver: ______________________

Considering this particular task as a whole, rank the following ten factors according to your estimate of their importance to successful task completion in the deep ocean.

Diving Factors	Rank
Visibility	
Communications to surface	
Communications to other divers	
Cold protection	
Freedom of movement	
Diver buoyancy control	
Diver stabilization	
Diver strength and/or endurance	
Special breathing gear	
Special tools	

Figure B-2. Diving factors form.

Task: ____________________ Team: ____________________

Date: ____________________ Diver: ____________________

No.	Task Element		Task Difficulty (check one)							Reason For Difficulty (Check as many as apply)																					
										Environ't					Dive Equipt						Task Equipt										
			Not Attempted	Could Not Do	Very Difficult	Difficult	Some Effort	Slight Effort	Very Easy	Cold	Diver Buoyancy	Current	Light Level	Turbidity	Suit	Fins & Boots	Communication	Scuba			Buoyancy	Size	Configuration	Electrical Syst	Mechanical Syst	Hydraulic Syst	Rigging & Anchors				
1																															
2																															
3																															
4																															
5																															
6																															
7																															
8																															
9																															
10																															
11																															
12																															

Figure B-3. Troubleshooting checklist.

HAND TOOLS

1. Compare the difficulty of performing the various task elements at 50 feet and 600 feet by placing a check mark in the appropriate column.

	Relative Difficulty				
Task Elements	Much Less	Less	Same	More	Much More
Mounting toolholder plate					
Selecting tools from tool-holder					
Using pipe wrenches					
Using box or open end wrenches					
Using crescent wrenches					
Using screwdrivers					
Using ratchet wrenches					

Figure B-4. Hand tools rating form.

SALVAGE TASKS QUESTIONNAIRE

Diver ____

Initials, Name — Rate/Rank — Service Number

GENERAL INSTRUCTIONS

You are to contrast the difficulty of performing the various salvage tasks at 600 feet with your actual experience in performing the same tasks at 50 feet. For example, when using the electric tool, if you found it more difficult to attach the tool box at 600 feet than at 50 feet, you will place a check mark in the column headed "More" (See Figure B-4).

The next question asks you to explain general reasons why the overall task was more difficult, if such was the case, as for example, greater cold or poorer visibility. Further, you are asked to explain why any of the task elements were more difficult, in this instance, making your answer specific to the task element in question.

For the remainder of the questions, please explain the reasons for your answers, pointing out both strong and weak points and making recommendations for corrective action when such is indicated. Your answers following the shallow-water trials were generally very thorough and were of the type we would appreciate receiving.

NOTE: The original of this questionnaire is to be turned in to the team leader.

HUNLEY-WISCHHOEFER SYSTEM

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any or all of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular task elements.

3. Could the system be adjusted to neutral buoyancy without difficulty?

4. Could the system be adjusted to positive buoyancy without difficulty?

5. Did you have difficulty moving the system about on the bottom?

6. Could the system be attached to a load without difficulty?

7. Could the safety pins and handles be removed without difficulty?

8. Do you believe the pins and/or handles would get lost under operational conditions?

9. Was there personal danger to the diver in releasing the messenger buoy for free ascent from the 600-foot depth?

10. Do you have any suggestions for improving the design or operational methods which you have not made previously?

11. Did you experience any problems that in any way might constitute a safety hazard?

12. Was the team size adequate?

13. Was the training adequate?

8.4-TON PONTOON

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular task elements.

3. Was the pontoon lowered close enough to the load clump to attach without having the pontoon moved?

4. Was the pendant cable at the bottom of the pontoon free to attach to the load clump?

5. Did the pontoon inflate and deflate properly?

6. Do you have any suggestions for improving the operational methods or design of the equipment?

7. Were any of the tasks involved in working with the pontoon hazardous at the 600-foot level?

8. Was the team size adequate?

9. Was the training adequate?

200-POUND LIFT HYDRAZINE DEVICE

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any or all of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular task elements.

3. Did the buoyancy adjustment zipper function satisfactorily?

4. Could the hydrazine fuel control valve be operated with heavy gloves?

5. Could a load be moved on the bottom with relative ease?

6. Could the system be shackled and unshackled from loads easily?

7. Did the generator supply adequate gas?

8. Should the available gas supply be increased for operations where repeated use is required?

9. Do you have any recommendations for improving the design or operational methods?

10. Did you experience any problems that might possibly develop into a safety hazard?

11. Was the team size adequate?

12. Was the training adequate?

TWO-TON LIFT PONTOON

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any or all of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular task elements.

3. Could the system be moved about on the bottom with relative ease?

4. Could the generator control valve be operated easily?

5 Could the vent control valve and lanyard be operated easily?

6. Could the system be shackled and unshackled from the loads easily?

7. Did the generator supply adequate gas?

8. Do you have any recommendations for improving the design or operational methods?

9. Did you experience any problems that might possibly develop into a safety hazard?

10. Was the team size adequate?

11. Was the training adequate?

25-TON LIFT PADEYE

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any or all of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular task elements.

3. Did you experience excess difficulty in moving or positioning the padeye?

4. Did you experience difficulty in removing the safety pins or attaching the lanyard? Firing the projectiles?

5. Do you have any recommendations for improving the design of the equipment or operating methods?

6. Did you experience any problems that might possibly develop into a safety hazard?

7. Was the team size adequate?

8. Was the training adequate?

CHEMICAL OVERLAY BOTTOM STABILIZATION

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any or all of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular task elements.

3. Did you experience any problems that in any way might constitute a safety hazard?

4. Did you experience difficulty in turning on the air and chemical supply valves?

5. Did you experience any difficulty with the applicators?

6. Did you find swim fins or anklet weights most effective for bottom-oriented tasks?

7. Did you experience any difficulty obtaining a smooth even flow of chemical overlay?

8. Do you think the equipment produced a good enough bottom cover to be useful for salvage work?

9. Have you any suggestions for improving the design or operational methods?

10. Was the team size adequate?

11. Was the training adequate?

EXPLOSIVELY ACTUATED STUD DRIVER

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any or all of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular task elements.

3. Did you experience any difficulty loading or removing the barrels?

4. Could you center the studs accurately in the holes or marked circles?

5. Could you hold the gun at right angles to the test plate without excess difficulty?

6. How many misfires did you have? Did they eventually fire?

7. Could you cock and fire the gun easily?

8. Was the recoil excessive?

9. Was the weight of the tool excessive?

10. Do you have any suggestions for improving the design or operational methods?

11. Was the penetration of all of the studs satisfactory?

12. Was the team size adequate?

13. Was the training adequate?

14. Did you experience any problem that might possibly constitute a safety hazard?

EXPLOSIVELY ACTUATED CABLE CUTTER

1. Could the cutter be positioned on the cable easily?

2. Could the safety pin be removed easily?

3. Did the lanyard provide a satisfactory means of firing the cutter?

4. How many misfires did you have?

5. Was the cable cut satisfactorily?

6. Was the tool weight excessive?

7. Do you have any suggestions for improving the design or operational methods?

8. Was the team size adequate?

9. Was the training adequate?

10. Did the concussion bother you?

11. Do you consider the cutter to be absolutely safe for underwater work?

ELECTRIC UNDERWATER POWER TOOL

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any or all of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular task elements.

3. Did you experience any problems that in any way might constitute a safety hazard?

4. Did the tool box stay in place using the support platform and magnets?

5. Were the tool bits, adapter, and impactor readily accessible in the tool box?

6. Could the tool bits be attached and removed without difficulty?

7. Could the impactor be attached to and disconnected from the motor without difficulty?

8. Did the tool bits wobble excessively?

9. Was the drilling operation satisfactory?

10. Did the drill jam often?

11. Did the impactor supply adequate torque for tapping?

12. If you have used a 5/8-hp drill motor on land, how did the torque generated by the power tool compare?

13. Could the taps be backed out of the test plates easily?

14. Did you have any difficulty using the hole saw?

15. Did the impactor work satisfactorily for running-in and removing bolts?

16. Did you have difficulty keeping the tool bits aligned at right angles with the work plate?

17. Were the ON-OFF and REVERSE switches comfortable to use?

18. Could the reverse switch be activated accidentally?

19. Was the position of the reverse switch satisfactory?

20. Do you believe the motor produced enough torque via the impactor to be practical for salvage work?

21. Was the weight of the tool in the water satisfactory?

22. Was the design of the handle satisfactory from both the comfort and control standpoints?

23. Did the power cord interfere with your work?

24. Do you consider the tool absolutely safe to work with?

25. Do you think the safety control unit is rugged and waterproof enough for shipboard use?

26. Do you think a removable-bar handle should be added to the tool considering the developed horsepower as a full 5/8?

27. Can you make any recommendations for improving the design of the motor, impactor, tool bit adapter, or tool bits that you have not made before?

28. Was the team size adequate?

29. Was the training adequate?

AIR-DRIVEN SAW

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any or all of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular task elements.

3. Could you change blades under water with reasonable ease?

4. Was the allen wrench too small to handle or difficult to store without accidental loss?

5. Did the saw cut fast enough to be practical for salvage work?

6. Was the handle and trigger comfortable?

7. Did it require excessive down pressure to cut at a reasonable rate.

8. Do you have any recommendations for improving the design or operation of the tool?

9. Did you encounter any problems that might possibly develop into a safety hazard?

10. Was the training adequate?

HAND TOOLS

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any or all of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular tasks.

3. Which wrench did you find most effective to work with—the crescent, box end,or open end?

4. Which screwdriver did you prefer for these tests?

5. Was the ratchet wrench easier or more difficult to use than the screwdrivers?

6. Could the desired tools be obtained from the toolholder plate easily?

7. Do you have any suggestions for improving the design or operational methods?

8. Was the training adequate?

9. Were the palm-grip screwdrivers easier or faster to use than conventional screwdrivers?

10. Was the selective-socket driver easier or harder to use than the 7/16-inch socket with the palm-grip handle?

CHEMICAL LIGHTS

1. Did the chemical pencil-light provide adequate light for identification of parts,________; for close hand work, ________ ; for illumination of large objects________?

2. Did the chemical packet-light provide adequate light for identification of parts,________; for close hand work,________; for illumination of large objects________?

3. Estimate the range at which the lights would be visible to a diver:

pencil-light________

packet-light________

spherical beads ________ (if provided)

4. Did you have any difficulties associated with the cage in which the lights were transported?

TOOL TEST STAND

1. Compare the difficulty of performing the various task elements at 50 and 600 feet by placing a check mark in the appropriate chart column.

2. If any or all of the task elements were more difficult to accomplish at 600 feet, please explain. First list general reasons and then explain why any of the task elements were more difficult, if the reasons were specific to particular task elements.

3. Could the test backing plates be aligned without difficulty?

4. Could the camera boom sections be added without difficulty?

5. Did you experience any difficulty in mounting the TV camera and lights?

6. Could you adjust the camera and lights to the correct position and angle without difficulty?

7. Was the boom adequately stable when fully extended?

8. Do you have any recommendations for improving the design or operational methods?

9. Was the team size adequate?

10. Was the training adequate?

Appendix C

PLANNED DIVER'S DAILY WORK SCHEDULES FOR SEALAB III—TEAM TWO

The following daily schedules represent the division of work, encompassed by the Supervisor of Salvage sponsored SEALAB III projects, into subtasks assigned to accomplish a complete test sequence during a succession of dives. Daily work schedules do not necessarily have to be performed in chronological order as outlined, with the exception of Day "Echo" (first work day, Schedule V) and "Last Day" (Schedule X).

I. Day "Alpha"

A. Topside Procedure Prior to First Dive

1. Topside personnel will prepare the Hunley-Wischhoefer buoy and fairing assembly as outlined in the Hunley-Wischhoefer Operation and Maintenance Manual. (For SEALAB III: add 16 lead weights to the skirt. Empty the toroid and close both valves. Add 75 pounds of shot to sink the assembly.)
2. Notify the divers that the Hunley-Wischhoefer buoy is ready to be lowered.
3. Lower the buoy and fairing (with chain, shackles, and male spear attached) over the side by ship's line attached to the padeye at the top of the buoy.
4. Notify the divers that the assembly has reached bottom.

B. Diver Procedure, First Dive

1. Ready the test divers. Receive the message that the Hunley-Wischhoefer buoy is ready to be lowered.
2. Leave the habitat.
3. Locate the Hunley-Wischhoefer assembly.
4. Adjust the assembly to neutral buoyancy. Bleed shot and/or flood the toroidal ballast chamber as required. (If removal of a skirt weight is required, it must be replaced before step 10.

5. Disconnect ship's line from Hunley-Wischhoefer buoy.
6. Signal the ship to retrieve the line.
7. Swim or walk the Hunley-Wischhoefer assembly to the 30-ton load clump.
8. Connect the shackle on the free end of the prod chain to a padeye on the 30-ton load clump.
9. Flood the toroidal ballast chamber.
10. Notify topside that the Hunley-Wischhoefer buoy is ready to be released.
11. Remove both locking pins from the release handles of the Hunley-Wischhoefer system.
12. Pull both release handles clear, releasing the buoy. (For SEALAB III buoy becomes 35 pounds positive.)
13. Return to the habitat.

C. Topside Procedure, Prior to Second Dive

1. When the buoy-fairing assembly reaches the surface, the ship will retrieve the assembly and bring it on board (Figure 2).
2. The 1/2-inch polypropylene messenger line will be drawn up tight by hand and secured. The line will then be either cut or uncoiled completely from the drum and the line end fed through the female overshot.
3. Shackle the 1,500 feet of 3/4-inch nonspin wire rope to the female overshot bridle and use it to lower the female overshot device down the 1/2-inch polypropylene messenger line (Figure 4).
4. The mating phase of the recovery system operation at the load clump will be observed on the TV monitor. If the female overshot fails to engage with the male connector, topside will raise the female assembly 20 or 30 feet, taking up any slack in the messenger line. Again lower the load line with the female assembly. When the engagement is made, a slight strain will be taken on the load line to ensure that the recovery system is firmly attached.

Slack off to prevent ship surge from lifting the 30-ton clump.

5. Attach the free end of the 8.4-ton pontoon load pendant to the top padeye of the 8.4-ton pontoon (Figure 35).

6. Rig the 8.4-ton pontoon to follow the 3/4-inch nonspin wire rope guideline to the load clump by shackling one end of the 4-foot, 1/2-inch wire rope distance cable to the padeye at the top of the 8.4-ton pontoon and the other end around the guideline, using a 3/4-inch shackle which is free to slide down the guideline. Lower the pontoon to the bottom, using a 3-inch-circumference line attached to the pontoon top padeye. The 1-1/4-inch airhose will be married to this line every 50 feet by means of nine-thread rolling hitches (Figure 35).

7. Signal divers when the 8.4-ton pontoon is on the bottom.

D. Diver Procedure, Second Dive

1. Receive the message that the 8.4-ton pontoon has been lowered to the bottom.

2. Divers leave the habitat.

3. Retrieve the end of the cable pendant which is attached to the top of the 8.4-ton pontoon.

4. Remove the 4-foot distance cable from the guideline.

   NOTE: Replace the shackle on the distance cable and leave the distance cable hanging on the pontoon.

5. Cut the 1/2-inch polypropylene messenger line from the Hunley-Wischhoefer device and signal the ship to retrieve it from the surface.

6. Shackle the pontoon load pendant to one of the three central padeyes on the 30-ton load clump.

   NOTE: Do not attach to certain designated small padeyes (Figure 34).

7. Unshackle the mated Hunley-Wischhoefer male prod and overshot assembly from the load clump.

8. Return to the habitat.

9. Signal topside to retrieve the 3/4-inch nonspin wire rope with the Hunley-Wischhoefer prod and overshot device attached.

10. Signal topside to inflate the 8.4-ton pontoon.

11. When bubbles appear from either bottom or top pontoon relief valve, signal topside that inflation is complete.

12. Signal topside to deflate the pontoon.

E. Topside Procedure Prior to Third Dive

1. Retrieve the 1/2-inch polypropylene messenger line.

2. On signal from the divers, retrieve the 1,500-foot, 3/4-inch wire rope with the Hunley-Wischhoefer prod and overshot device attached.

3. On signal from the divers, inflate the 8.4-ton pontoon.

4. On signal from the divers, deflate the 8.4-ton pontoon.

F. Diver Procedure, Third Dive

1. Leave the habitat.

2. Unshackle the pontoon from the 30-ton load clump.

3. Return to the habitat.

4. Signal topside to retrieve the 8.4-ton pontoon.

G. Topside Procedure Following Tests

1. On signal from the divers, retrieve the 8.4-ton pontoon.

II. Day "Bravo"

A. Topside Procedure Prior to First Dive

1. Prepare the Hunley-Wischhoefer buoy and fairing assembly as outlined in the Hunley-Wischhoefer Operation and Maintenance Manual, with a complete 25-ton padeye

assembly attached (Figure 1). Skirt and weights need not be attached. Add 100 pounds of lead shot. Empty the toroidal chamber and close both valves.

2. Secure the H-W buoy release handles so they cannot be removed by divers. (Use the chain provided and secure the open link.)

3. Notify the divers that the H-W buoy with the 25-ton padeye attached is ready to be lowered (Figure 1).

4. Lower the buoy and fairing assembly (with chain, shackles, male spear, <u>and assembled 25-ton padeye attached)</u> with the ship's line.

5. Notify the divers that the assembly has reached bottom. Slack off on the ship's line—enough to prevent surge on line with rise and fall of ship on swells.

B. Diver Procedure, First Dive

1. Ready the test divers. Receive the message that the H-W assembly with the 25-ton padeye attached has been lowered to bottom.

2. Leave the habitat.

3. Locate the H-W assembly.

4. Adjust the assembly to neutral buoyancy. Bleed shot and/or flood the toroidal ballast chamber as required.

5. Disconnect the ship's line from the H-W buoy. Retain the line and walk it to the tool test stand and tie it off.

6. Swim or walk H-W buoy and 25-ton padeye to the tool test stand.

7. Position the 25-ton padeye on its test plate (Figure 12).

8. Pull the safety pin on <u>one</u> stud driver.

9. Move back 10 feet and fire that stud driver.

10. Repeat steps 8 and 9 for the remaining three stud drivers, one at a time.

11. Using hand tools (attached to the plate by line), unbolt the padeye test plate from the tool test stand. Check that it is clear for lifting.

    NOTE: If the hand wrenches cannot be located attached to the test plate, use wrenches from the hand-tool test equipment but ensure that they are returned to their proper place.

12. Reattach the ship's lifting line.

13. Return to the habitat.

14. Notify topside to retrieve the H-W system with padeye and test plate attached.

C. Topside Procedure After First Dive

1. USNS ***GEAR*** retrieve the H-W system with padeye and test plate attached.

2. Notify the divers that the H-W assembly is aboard.

D. Diver Procedure, Second Dive

1. Leave the habitat.

2. Proceed to the tool test stand. Remove the screen cover from the sand tray (Figure 16).

3. Open the air bottle valve. The regulator on the tank is set for 100 psi above ambient (Figure 15).

   CAUTION: Make certain that the 3-way valve is in the OFF position (Figure 15).

4. Open AIR and OVERLAY valves (Figure 15). These are the two angles valves; they should be opened wide.

5. Open the 3-way valve to AIR. Purge the hose. While so doing, hold the applicator in the same position as required for operation (Figure 15). Purging should take only a few seconds.

6. Switch the 3-way valve to OVERLAY. This should be done in one smooth motion. As the overlay material starts down the hose, the air will be expelled before it. Hold the applicator over the sand tray (Figure 16).

7. Apply the overlay chemical in three or four passes. Lap each pass 3 to 6 inches. If any particles lodge in the applicator slot, the overlay will have holidays. Try to cover these if possible. If desired, passes 90 degrees to the first can be made.

8. Turn the 3-way valve off (valve handle straight down).

9. Close both the AIR and OVERLAY valves.

10. Put the applicator in the canvas bag (Figure C-1). Secure the bag with drawstring.

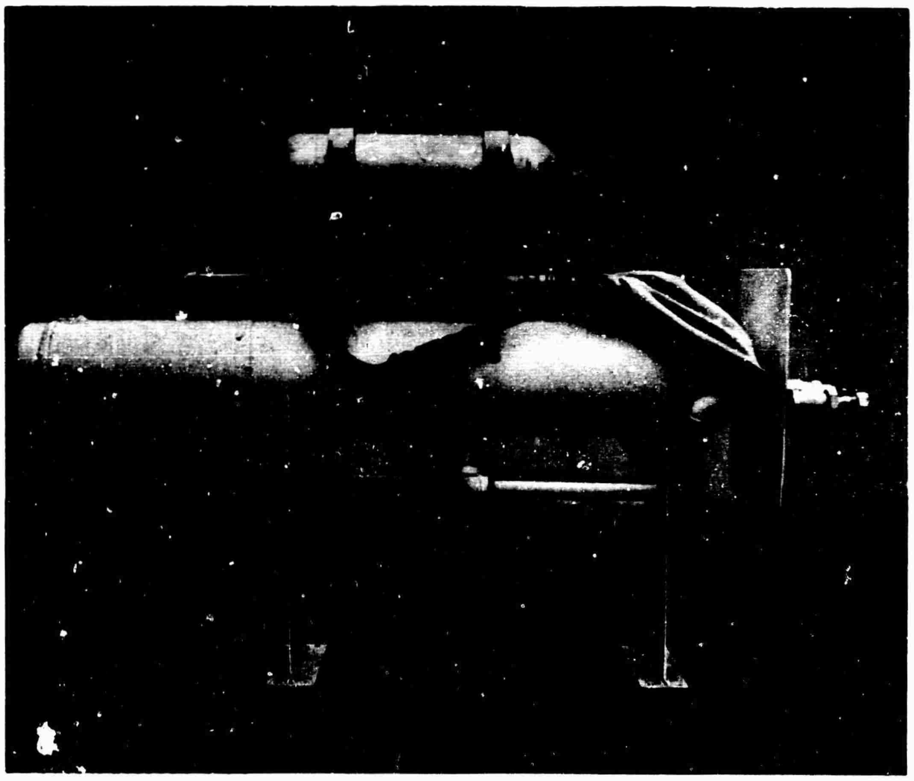

Figure C-1. Chemical overlay equipment with spreader in canvas bag.

NOTE: Assistance from partner will help. Practice this procedure at the start of the test.

11. Replace the screen sand tray lid. The tray has been built so the screen lid can be first laid on the front edge and then pushed back into the slot.

12. Close the air bottle valve.

13. Open the VENT valve. Do so slowly to vent overpressure. Leave the valve open so pressure will equalize as the test stand is raised to surface.

    NOTE: Be sure to bleed off air when the test is complete. Use the relief valve included for that purpose. Basic instructions are printed on test equipment.

E. Diver Procedure, Third Dive

1. Leave the habitat; proceed to the tool test stand.
2. Remove the chemical light packets (Figure 17) from the transport cage (Figure 49).
3. Demonstrate the pencil-type light.
   a. Break center vial by bending.
   b. Shake to mix chemical.
4. Demonstrate the packet-type light.
   a. Remove the clip from across the center of the bag.
   b. Knead the bag to mix chemicals well.
5. Return packets to the transport cage and secure the cage cover.
6. Return to the habitat.

III. Day "Charlie"

A. Topside Procedure Prior to First Dive

1. Prepare the 200-pound lift hydrazine device (Figures 9 and 10) and a 25-ton padeye assembly (Figure 12) as directed. Do not load studs into the barrels.

2. Attach extra lashing materials to the padeye for diver's use in step B7 below.

3. Lower the assembled 200-pound lift hydrazine device and 25-ton padeye to bottom by ship's line using a 3-inch-circumference line.

B. Diver Procedure, First Dive

1. Ready the test divers. Receive the message from topside that the 200-pound lift hydrazine device with 25-ton padeye has been lowered to the bottom.

2. Divers leave the habitat.

3. Locate the hydrazine lift unit and padeye.

4. Remove the ship's lowering line from the lift device and attach it to the padeye on 30-ton load clump (Figure 34) to serve as a guideline.

5. Adjust the lift device, with padeye attached, to neutral buoyancy.

6. Move the lift device and padeye assembly to the 30-ton load clump.

7. Place the 25-ton padeye on one of the outboard beams of the load clump to simulate placing of a padeye for firing. Adjust the lift device so that the lift/padeye assembly is approximately 25 pounds negatively buoyant.

   NOTE: Keep fingers clear of the underside of the padeye magnets. Only two padeye magnets need be in contact with the beam for this exercise but the padeye should be secured to the beam by lashing.

8. Return to the habitat.

C. Topside Procedure After First Dive

1. Prepare the 2-ton lift hydrazine pontoon (Figure 8) as directed.

2. Lower the 2-ton lift pontoon on the ship's nonspin line along the guideline to the bottom, using a 1/2-inch, 4-foot distance wire.

3. Notify the divers that the 2-ton lift pontoon is on the bottom.

D. Diver Procedure, Second Dive

1. Receive the message from topside that the 2-ton lift pontoon has been lowered to the bottom.
2. Divers leave the habitat.
3. Shackle the 2-ton lift pontoon to the 30-ton load clump (Figure 34).
4. Disconnect the distance wire from the guideline, and notify the ship to retrieve the guideline.
5. Open the hydrazine control valve on the 2-ton lift pontoon.

   NOTE: When gas bubbles from the bottom vent, the pontoon is fully inflated.
6. Close the control valve.
7. Return to the habitat.

E. Topside Procedure During Second Dive

1. Retrieve the guideline.

F. Diver Procedure, Third Dive

1. Leave the habitat.
2. Deflate the 2-ton lift pontoon by pulling the top vent valve lanyard. The valve must be held open until the pontoon is completely deflated.
3. Unfasten the 200-pound lift hydrazine device and 25-ton lift padeye from the load clump and set them on the sea floor.
4. Shackle the end of the load pendant wire from 2-ton lift pontoon onto the top of the 200-pound lift hydrazine unit.
5. Release gas from the 200-pound lift hydrazine device by moving the zipper slide to the top of the unit.

6. Return to the habitat.

7. Signal topside to lift the 2-ton lift hydrazine pontoon, 200-pound lift hydrazine system, and 25-ton padeye to the surface.

G. Topside Procedure After Third Dive

1. Raise the 2-ton lift pontoon and attached 200-pound lift hydrazine device with 25-ton padeye to the surface and take them aboard.

IV. Day "Delta"

A. Topside Procedure Prior to First Dive

1. Prepare the Hunley-Wischhoefer buoy and fairing assembly as outlined in the Hunley-Wischhoefer Operation and Maintenance Manual. Add 16 lead weights to the skirt. Empty the toroidal ballast chamber and close both valves. Add lead shot (75 lb) to sink the assembly.

2. Lower the H-W assembly to the bottom.

3. Notify the divers that the H-W assembly is on the bottom.

B. Diver Procedure, First Dive

1. Ready the test divers. Receive the message that the H-W assembly has been lowered.

2. Leave the habitat.

3. Locate the H-W assembly.

4. Disconnect the ship's lowering line from the H-W buoy and signal the ship to retrieve it.

5. Adjust the assembly to neutral buoyancy. Bleed shot and/or flood the toroidal ballast chamber as required. If removal of a skirt weight is required, it must be replaced prior to step 9.

6. Move the assembly to the 30-ton load clump.

7. Shackle the H-W chain to a large central padeye on the 30-ton load clump (Figure 34).

8. Flood the toroidal ballast chamber.

9. Signal topside that the H-W device is ready to be released.

10. Release the H-W buoy.

11. Return to the habitat.

C. Topside Procedure During First Dive

1. Retrieve ship's lowering line.

D. Topside Procedure Following First Dive

1. Retrieve the H-W buoy-fairing assembly from the surface and take it aboard ship (Figure 2).

2. The 1/2-inch polypropylene messenger line will be severed and threaded through the female overshot device, after which, it will be drawn up tight by hand and secured on deck.

3. Shackle the 8.4-ton pontoon to the H-W female overshot bridle. Attach the 1-1/4-inch airhose to the pontoon. Attach the 3-inch-circumference line to the top padeye of the 8.4-pontoon.

4. Lower the pontoon and overshot device (Figure 7) on the 3-inch-circumference line down the H-W polypropylene messenger line to the bottom. If it becomes necessary to decrease the buoyancy of the pontoon, entrapped air in the pontoon can be released by opening the valve at the airhose connection on the ship.

5. Test for hookup of the female overshot with the male prod (Figure 3).

6. When hookup is made, inflate the 8.4-ton pontoon. Check the TV monitor for complete inflation by observing when air bubbles rise from the pontoon relief valves.

7. Deflate the 8.4-ton pontoon.

8. Notify the divers when the pontoon is deflated.

9. Slack off on the 3-inch line to prevent ship surge affecting the pontoon.

E. Diver Procedure, Second Dive

1. Leave the habitat.

2. Cut the 1/2-inch polypropylene messenger line.

3. Signal the ship to retrieve the 1/2-inch messenger line.

4. Unshackle the H-W mated prod/overshot device from the 30-ton load clump padeye, and check to assure that the assembly is clear for lifting.

5. Return to the habitat.

6. Signal topside to raise the 8.4-ton pontoon assembly.

V. Day "Echo" <u>ASSIGNED AS FIRST WORK DAY FOR TEAM TWO</u>

A. Topside Procedure, Prior to First Dive

1. Lower the tool test stand, (Figure 49) with hand tools (Figures 26 and 27) in bin boxes, to the bottom.

2. Notify the divers that the tool test stand is on the bottom.

B. Diver Procedure, First Dive

1. Ready the divers. Receive the message that the tool test stand has been lowered to the bottom.

2. Leave the habitat.

3. Proceed to the tool test stand. (Assure that the stand is properly located.)

4. Remove the ship's lowering line from the tool test stand.

5. Orient the test stand backing plates and lock them in position.

6. Extend both camera booms by adding sections. Position the T-sections and lock them in place.

7. Go to the habitat.

8. Remove the TV camera from its habitat bracket.

9. Carry the TV camera to the tool test stand and mount it on a T-section camera mount (Figure 49).

10. Return to the habitat for "snooper" lights.

11. Remove two lights from habitat brackets.

12. Carry the lights to the tool test stand and mount them on the T-section with the camera.

13. Unlock the T-section and adjust to the position for TV coverage of the test in progress.

14. Replace the lowering shackle on the tool test stand padeye.

15. Return to the habitat.

VI. Day "Foxtrot"

The procedures for Day Foxtrot are intended to be repeated on a succeeding day with participating divers reversing first and second dive schedules to permit completion of test procedures by four individuals. Divers exercising the equipment on the second day will utilize the unused test plates. This will require moving the "snooper" lights and TV camera to the second boom.

A. Topside Procedure, Prior to First Dive

1. Prepare the cable cutters (Figure 20) and explosively actuated stud drivers (Figure 23) for testing. Prepare the 200-pound lift hydrazine device (Figure 9).

2. Lower the explosively actuated stud drivers, loaded barrels, cable cutters, 200-pound lift hydrazine device, and attendant gear by underwater upside-down davit (UUDD) open cage.

3. Notify the divers that the UUDD cage is down.

B. Diver Procedure, First Dive

<u>NOTE:</u> In case of a failure of one of the explosively actuated stud drivers or cable cutters, continue the test with the second stud driver or cable cutter to complete as much of the exercise as possible.

If any dive time remains, the hand tools are to be exercised (see Day "India").

Be sure all explosively actuated equipment and the 200-pound lift hydrazine device are sent to th[illegible]ace via UUDD before returning to the habitat.

1. Ready the test divers. Receive the message that the equipment is down.
2. Leave the habitat.
3. Proceed to the UUDD open cage.
4. Remove the two stud driver handling bags and 200-pound lift hydrazine device from the UUDD open cage.
5. Hang the tool bags on the lift device.
6. Adjust the lift device with tool bags attached to neutral buoyancy.
7. Transport the equipment to the tool test stand and secure the lift device to the stand.
8. Return to the habitat.

C. Diver Procedure, Second Dive

1. Locate the tool bag containing the barrels <u>without</u> plastic centering plugs.
2. Load a barrel into an explosively actuated stud driver.
3. Move to the yellow test plate with blue circles.
4. Utilize the tethering strap as required to hold self against the workpiece (Figure 48).
5. Place the muzzle of the stud driver against the test plate in the blue circle at the 12 o'clock position, twist the barrel-guide, push against the test plate, pull the trigger.

NOTE: Safety Precautions

a. At no time during stud firing will any person allow any part of his body to extend beyond the plane of the test plate.

b. If a cartridge fails to fire when the trigger is pulled, remain in position against the workpiece. Release the trigger and pull it again. If the driver still does not fire, hold the position against the work surface for 30 seconds after the last trigger pull as a safeguard against the possibility of a delayed discharge, then remove the barrel.

6. Remove the barrel and place it in the empty bag.

7. Install a new barrel into the stud driver.

8. Repeat the above procedure, driving studs into all 12 blue circles.

9. Remove one cable cutter from the tool bag.

10. Remove the safety block from the cable cutter.

11. Position the cable cutter on the 1-inch-diameter test cable by pushing the torsion spring against the test cable and allowing the cable to slip into the cutter jaw so that the spring supports the cutter.

12. Pull the ring to remove the safety pin.

13. Pull the lanyard to fire the cutter. (This requires an approximate 14- to 20-pound pull.)

14. Place the expended cutter in the bag with used stud driver barrels.

    NOTE: If a cable cutter fails to remain in position on the test cable by itself, it can be fired safely while holding the cutter in position with one hand and pulling the lanyard with the other. Be sure to keep hands clear of the cable while firing.

15. Pick up the second diver's tool bag. Stud driver barrels in this bag will have plastic centering plugs in the outer end of the barrel.

16. The second diver will place a barrel in the stud driver and position himself in front of the predrilled test plate which has square yellow markings.

17. Place the stud driver so the plastic centering plug fits into the predrilled hole at the 12 o'clock position on the test plate.

18. Fire the projectile, as before (step C5).

19. Remove the expended barrel and place it in the empty bag.

20. While the diver is changing barrels, his partner will clean the threads on the driven stud with a wire brush and install a washer and nut, handtight.

21. Repeat the above procedure for the remaining 11 holes.

22. Tighten all 12 nuts with the double end wrench provided.

23. Remove one cable cutter from the tool bag.

24. Repeat steps C10 thru C14.

25. Using the 200-pound lift hydrazine de[illegible]e, return all barrels and equipment to the UUDD dumbwaiter off-loading site and send them to the surface.

    NOTE: Divers should alternate duties so that each one fires some of each stud type and a cable cutter.

D. Topside Procedure, After Second Dive

   1. Receive equipment from the UUDD.

VII. Day "Golf"

The procedures for Day Golf are intended to be repeated on a succeeding day with participating divers reversing dive schedules to permit completion of test procedures by four individuals. Divers exercising the equipment on the second day will utilize the unused test plates. This will require moving the "snooper" lights and TV cameras to the second boom.

A. Topside Procedure, Prior to First Dive

   1. Alert the habitat personnel.

   2. Send the electric underwater power tool (Figure 18) with power cord and accessory tool box (Figure 19) to the habitat by dumbwaiter open cage (UUDD). The power cord shall have the dummy electrical connector installed.

17. Place the stud driver so the plastic centering plug fits into the predrilled hole at the 12 o'clock position on the test plate.

18. Fire the projectile, as before (step C5).

19. Remove the expended barrel and place it in the empty bag.

20. While the diver is changing barrels, his partner will clean the threads on the driven stud with a wire brush and install a washer and nut, handtight.

21. Repeat the above procedure for the remaining 11 holes.

22. Tighten all 12 nuts with the double end wrench provided.

23. Remove one cable cutter from the tool bag.

24. Repeat steps C10 thru C14.

25. Using the 200-pound lift hydrazine device, return all barrels and equipment to the UUDD dumbwaiter off-loading site and send them to the surface.

    NOTE: Divers should alternate duties so that each one fires some of each stud type and a cable cutter.

D. Topside Procedure, After Second Dive

   1. Receive equipment from the UUDD.

VII. Day "Golf"

The procedures for Day Golf are intended to be repeated on a succeeding day with participating divers reversing dive schedules to permit completion of test procedures by four individuals. Divers exercising the equipment on the second day will utilize the unused test plates. This will require moving the "snooper" lights and TV cameras to the second boom.

A. Topside Procedure, Prior to First Dive

   1. Alert the habitat personnel.

   2. Send the electric underwater power tool (Figure 18) with power cord and accessory tool box (Figure 19) to the habitat by dumbwaiter open cage (UUDD). The power cord shall have the dummy electrical connector installed.

D. Diver Procedure, Second Dive

1. Leave the habitat

2. Proceed to the tool test stand

   NOTE: Proceed with tests as directed below. In case of failure of the electric tool equipment, exercise hand tools until the end of the scheduled dive time (see Day "India"). The failed unit shall be sent topside at the end of the dive.

3. The first test diver will buckle on the tethering strap.

4. Drill six 3/16-inch pilot holes.

5. Drill two 27/64-inch and two 5/8-inch holes using the pilot holes.

6. Cut a 3/4-inch and a 1-1/2-inch hole using the remaining pilot holes.

7. Attach the impactor unit to the electric tool.

8. Tap two holes with the 1/2-inch tap.

9. Run two 1/2-inch bolts into the tapped holes.

10. Remove the impactor.

11. Center punch for one new hole, to aid in locating a pipe coupling assembly.

12. Drill a 3/16-inch pilot hole at the center punch imprint.

13. Enlarge the hole with a 27/64-inch drill.

14. Attach the impactor unit and tap the 27/64-inch hole with a 1/2-inch tap.

15. Locate the pipe coupling assembly and hand start a 1/2-inch bolt.

16. Attach a socket and run the 1/2-inch bolt down.

17. Remove the impactor unit.

18. Center punch and drill pilot holes for the two remaining mounting bolts.

19. Drill to enlarge, tap, and run bolts in the two holes.

20. Using the pipe coupling as a guide, hole saw a 1-1/2-inch hole through the test plate.

21. Remove three of the pretorqued bolts and nuts from the test plate.

22. Move to the stud driver test plates and impact existing nuts on three of the explosively actuated driven studs across the top of the plate.

23. Exchange duties with the second test diver who will repeat steps 3 thru 22 above, using the second test plate. He will impact the three nuts across the bottom of the explosively actuated stud driver test plate.

24. Secure the equipment at the site for use by the second team on a succeeding day.

    NOTE: When all testing is completed by both teams, disconnect the power cord from the safety circuit and pass the power cord outside the habitat. Move all related loose equipment to the dumbwaiter and send it topside.

VIII. Day "Hotel"

A. Topside Procedure, Prior to First Dive

1. Alert the habitat personnel.

2. Send the air-driven saw (Figure 25) equipment with airhose and extra blades to the habitat by dumbwaiter, open cage. Spare allen wrench screwdriver blades will be provided in the tool test stand tool bin. (An allen wrench is required to change a broken or dulled blade.)

3. Ensure that the lubricating oil vial is filled.

B. Diver Procedure, First Dive

1. Ready the test divers. Receive the message that the equipment is down.

2. Leave the habitat.

3. Receive the equipment at the dumbwaiter off-loading site.

4. Move the equipment to the habitat pneumatic tool connection.

5. Attach the airhose to the connection.

6. Move the equipment to the tool test stand.

7. Exercise a saw by cutting steadily on the saw test plate for 5 minutes.

   NOTE: Each diver will time his partner for a 5-minute test period.

8. Measure and report the length of each cut made in a 5-minute period.

   NOTE: Grid markings to a minimum of 1/4-inch are provided on the saw test plates.

9. Exercise the hand tools (see Day "India").

10. Return to the habitat.

C. Diver Procedure, Second Dive

1. Leave the habitat.

2. Move to the tool test stand.

3. Each diver will make a cut on the unused saw test plate with an air-driven saw for 5 minutes while a second diver keeps time.

   NOTE: This will require moving the "snooper" lights and TV camera.

4. Measure and report the length of each cut for each 5-minute test period.

5. Exercise the hand tools until the end of scheduled dive period (see Day "India").

6. Move the saw equipment to the habitat.

7. Disconnect the airhose from the habitat outlet.

8. Move the equipment to the dumbwaiter and send it topside.

9. Return to the habitat.

IX. Day "India"

A. Diver Procedure, Identical for First and Second Dives.

1. Proceed to the tool test stand and remove the hand tool mounting rack and tools (Figures 26 and 27) from the tool bin on the stand and arrange them as shown. Proceeding as outlined below, the tools will be exercised on the test plate shown in Figure 49 (test plate on right side of test stand).

	EXERCISE	TOOL
a.	Loosen the pipe nipple and coupling and retighten.	14" pipe wrench
b.	Loosen the hydraulic union and retighten.	14" crescent wrench
c.	Loosen six round head screws and retighten.	6" screwdriver
d.	Loosen six Phillips head screws and retighten.	Phillips screwdriver
e.	Loosen six allen head screws and retighten.	Allen screwdriver
f.	Loosen six hex head screws and retighten.	Socket and ratchet wrench
g.	Loosen the 3/4" bolt and nut and retighten.	14" crescent wrench
h.	Loosen the 3/4" bolt and nut and retighten.	1-1/2" box end wrench
i.	Loosen the 3/4" bolt and nut and retighten.	1-1/2" open end wrench
j.	Loosen the 5/8" bolt and nut and retighten.	14" crescent wrench

	EXERCISE	TOOL
k.	Loosen the 5/8" bolt and nut and retighten.	1-1/8" box end wrench
l.	Loosen the 5/8" bolt and nut and retighten.	1-1/8" open end wrench
m.	Loosen the 1/2" bolt and nut and retighten.	10" crescent wrench
n.	Loosen the 1/2" bolt and nut and retighten.	15/16" box end wrench
o.	Loosen the 1/2" bolt and nut and retighten.	15/16" open end wrench
p.	Loosen the 3/8" bolt and nut and retighten.	10" crescent wrench
q.	Loosen the 3/8" bolt and nut and retighten.	3/4" box end wrench
r.	Loosen the 3/8" bolt and nut and retighten.	3/4" open end wrench
s.	Loosen six round head screws and retighten.	Socket end screwdriver with palm-grip
t.	Loosen six Phillips head screws and retighten.	Socket end Phillips screwdriver with palm-grip
u.	Loosen six hex head screws and retighten.	Selective socket driver with palm-grip
v.	Loosen six 1/4" hex head screws and retighten.	7/16" socket with palm-grip

2. Replace tools in the tool box.
3. Return the tool box and tool mounting rack to the bin on tool test stand.
4. Return to the habitat.

X. Last Day

A. Topside Procedure, Prior to Third Dive

1. Lower the ships 3/4-inch nonspin wire rope to the bottom.
2. Notify the divers when the wire rope is at the bottom.
3. Receive the signal from the divers to raise the tool test stand.
4. Raise the tool test stand and take it aboard the USNS ***GEAR.***

B. Diver Procedure, Third Dive

1. Receive the signal that the ship's 3/4-inch nonspin wire rope line is on the bottom.
2. Leave the habitat.
3. Proceed to the tool test stand.
4. Remove the TV camera from the tool test stand.
5. Carry the TV camera to the habitat.
6. Mount the TV camera on its habitat bracket.
7. Return to the tool test stand.
8. Remove the two "snooper" lights from the tool test stand.
9. Carry the two lights to the habitat.
10. Mount the lights on their habitat brackets.
11. Return to the tool test stand
12. Remove the extensions from the camera and light booms.
13. Replace the boom extensions in their carrying brackets.
14. Fold both camera and light booms against their common tripod leg.
15. Clamp the booms in place.
16. Check and tighten all locking clamps on the tool test stand.

17. Retrieve the lower end of the ship's line.
18. Shackle the ship's line to the tool test stand lifting eye.
19. Return to the habitat.
20. Signal topside to raise the tool test stand.

Appendix D

SERVICES, FACILITIES, AND TEST EQUIPMENT LOGISTIC SUPPORT

Cognizant participating activities are required to provide support to the SEALAB Salvage Lift Systems and Underwater Tools Tasks as indicated below.

SUPERVISOR OF SALVAGE, USN (SUPSALV)

1. USNS ***GEAR*** (ARS-34) including crew for manning rigging
2. Coordination of topside equipment
3. Coordination with NCEL to ensure that all required equipment such as remote recovery system, salvage pontoon, hoses, air compressor, dynamometer, shackles, tool test stand, TV camera, and other necessary equipment are aboard the USNS ***GEAR*** or otherwise available. Ensure that the equipment is checked out and that all equipment is returned to its appropriate station at conclusion of the tests
4. Small boat for buoy retrieval
5. 1-1/4-inch airhose, 800 feet, including spares
6. Two Roylyn 1-1/4-inch quick-disconnect fittings
7. One 8.4-ton lift capability collapsible salvage pontoon

NAVAL UNDERWATER WARFARE CENTER, PASADENA, CALIFORNIA (NUWC)

1. Three polypropylene messenger line drums each containing 750 feet of 1/2-inch line
2. One male connector spear (prod)
3. One female overshot assembly
4. One buoy assembly
5. One conical fairing assembly

6. Three pairs of release handies
7. Three pairs of locking pins
8. Twenty 25-pound bags of no. 7 lead shot
9. Two high-strength die-lock shackles
10. One 2-foot length of die-lock chain
11. One storage stand
12. One dragskirt
13. One funnel (for loading shot)

SEALAB III DEEP SUBMERGENCE SYSTEMS PROJECT (DSSP)

1. "Snooper" TV and still camera
2. Two 1,000-watt "snooper" lights for camera coverage
3. Two teams of two divers each for the underwater handling of the salvage equipment throughout the tests. Also, additional diver(s) to provide TV and still photography coverage
4. Report by divers regarding personal findings resulting from the tests

NAVAL CIVIL ENGINEERING LABORATORY, PORT HUENEME, CALIFORNIA (NCEL)

1. One 30-ton load clump constructed from a steel ingot and housed in a steel frame with six padeyes. Dimensions of the load clump are 12 by 10 by 5 feet. (The clump has been positioned at the test site)
2. One tool test stand with test plates and cables
3. 800 lineal feet of 1-1/4-inch-diameter airhose with Roylyn quick-disconnect open couplings to mate with the Roylyn bronze quick-disconnect nipple no. 1022-20 on the salvage pontoon
4. Preliminary staging area for the test equipment
5. Preliminary diver's training test facilities

6. Personnel to observe the shallow and deep water tests.
7. Coordination with SUPSALV to ensure that all required equipment is aboard the USNS ***GEAR*** or otherwise available and that the equipment is checked out
8. Repository for recorded test data and visual observation debriefings of the divers
9. Preparation of final test and evaluation report
10. Coordination with SUPSALV to ensure that all test equipment is returned to its appropriate station
11. Ten feet of 1-inch chain or wire rope
12. Handling cables (1,500 feet nonspin, 3/4-inch improved plow steel, 21.8 tons breaking strength); (2,500 feet right regular lay, improved plow steel, 3/4-inch wire rope, fiber core, 22.6-tons breaking strength)
13. Shackles
14. 500 pounds, no. 7-1/2 lead shot
15. Distance cable, consisting of a 1/2-inch wire rope strap, 2 to 4 feet long
16. Chemical overlay tank, spreader, and materials
17. Chemical lights
18. Hand tools
19. Sixteen 13.5-pound lead weights
20. Air-driven saw and hose with accessories
21. Miscellaneous tools: marlinspike, sledge hammer, crescent wrench, pry bar, etc
22. Two 15-ton, Type 3, Mod GG Miller swivels
23. Three tool bags

NAVAL MISSILE CENTER, POINT MUGU, CALIFORNIA (NMC)

1. Personnel for human engineering and human factors analysis of tests

2. Human factors and diver performance measurement data sheets
3. Hand tool test plate and tool rack
4. Waterproofed instruction sheets

NAVAL WEAPONS CENTER, CHINA LAKE, CALIFORNIA (NWC)

1. Two-ton collapsible pontoon; hydrazine-fueled gas generator
2. Rigid, 200-pound, variable buoyancy, hydrazine-fueled gas generator lift system
3. All associated fuel, tools, repair kits, etc, for items 1 and 2

U. S. NAVAL ORDNANCE LABORATORY, SILVER SPRING, MD. (NOL)

1. Five cable cutters, Mk 20 Mod 0
2. Four explosively actuated stud drivers, Model D, including tool kits and assembly items
3. Thirty barrels for explosively actuated stud drivers
4. Thirty solid-stud projectiles for 1-inch mild steel plate
5. Thirty solid-stud projectiles for 1/2-inch mild steel plate
6. Two 25-ton lift capability padeyes with stud projectiles and four firing assemblies
7. HY-80 steel test plate

BATTELLE MEMORIAL INSTITUTE, COLUMBUS, OHIO

1. Electric underwater power tool with 200 feet of armored power cord
2. Safety circuit and motor start control
3. Tool box complete with all tools and attachments
4. Four test plates, two with pretorqued bolts

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13. ABSTRACT

The Navy is authorized by public statute to provide salvage facilities to assist both public and private vessels. In keeping with this responsibility, the Supervisor of Salvage, U. S. Navy, is prosecuting a vigorous program to incorporate the latest techniques and equipment into the Navy's salvage forces.

The SEALAB III program, under the direction of the Ocean Engineering Branch, Deep Submergence Systems Project Office, was initiated to advance the state-of-the-art of man's capability to live and work in the deep ocean environment. It is the goal of the Salvage Projects for SEALAB III to demonstrate and field test some of the more important new salvage devices and techniques.

This report discusses the aquanaut familiarization and training phases associated with the Salvage Projects planned for Team Two—SEALAB III, and the modifications to both equipments and procedures as suggested by the divers. Preliminary results are included with recommendations regarding future plans.

Human factors studies have been conducted in conjunction with the training phases and will be continued during SEALAB III. Goals include assessment of divers performance, the development of improved underwater work procedures, and improvement of underwater equipment design through development of design criteria. Results of these studies will be reported following completion of the SEALAB III program.

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